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DYNAMIC RESPONSE OF REINFORCED SOIL SYSTEMS VOLUME II: APPENDICES

R.C. BACHUS, R.J. FRAGASZY, M. JABER, K.L. OLEN, Z. YUAN, R. JEWELL

GEOSYNTEC CONSULTANTS
5775 PEACHTREE DUNWOODY ROAD
SUITE 200F
ATLANTA GA 30342

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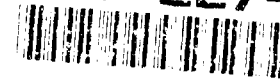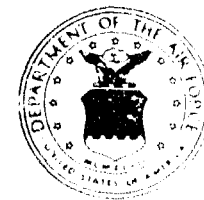
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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This report describes the results of a comprehensive laboratory, numerical and physical modeling investigation of the response of reinforced soil structures to blast loading. Dynamic laboratory pullout testing of geogrid and metal strip reinforcement embedded in cohesionless soil shows negligible rate effects with rise times to peak pullout load ranging from several minutes to less than 50 ms. Triaxial tests on fiber-reinforced soil show significant increases in peak strength, axial strain at peak strength and volume reduction with increasing fiber content.

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A numerical model was developed using the DYNA3D finite-element code. A numerical parametric study shows the importance of reinforcement stiffness, soil compaction and roof support on the response of a reinforced soil wall to blast loading.

Centrifuge model tests were conducted on 1:30 scale models of reinforced soil walls. Centrifuge results compare well to numerical predictions and full scale tests. Geogrid reinforced walls (modeled with nylon mesh) performed better than steel strip reinforced walls.

This technical report is divided into two volumes. Volume I contains the main body of the report and Volume II contains the Appendices.

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EXECUTIVE SUMMARY

A. OBJECTIVE

The objective of this study was to investigate the response of reinforced soil systems subjected to blast loading and to assess the feasibility of using reinforced soil to provide blast resistance. To meet this objective, a testing program was developed and executed to accomplish the following: (i) to establish the properties of reinforced soil subjected to blast loading, (ii) to develop numerical and physical modeling techniques which are appropriate for evaluating the response of reinforced soil systems subjected to blast loading, and (iii) to establish preliminary analysis methods which can be used for the design of reinforced soil systems subjected to blast loading.

B. BACKGROUND

Blast-protective structures are commonly used by the United States Air Force (USAF) and other branches of the armed forces to protect equipment, explosives, and personnel from conventional weapons effects. These effects include high-pressure impulse loading, projectile/fragment impact and penetration, and cratering. Currently, these structures are constructed either as heavily-reinforced concrete structures or as buried structures protected by a burster slab. These protection measures are costly, time consuming to construct, and sensitive to multiple strikes.

Soil has been used to increase the survivability of these structures by providing a cover or barrier to reduce the shock, pressure, and impact on the structures. However, soil berms must be built at relatively flat slopes (about 2.5 horizontal:1 vertical (2.5H:1V)) for adequate stability. Because of this, the use of a soil cover or berm is restricted by the amount of land available for construction and the logistics of moving large quantities of soil to the site.

The USAF has recently expressed interest in using reinforced soil in the development of blast-protective structures. Reinforced soil is a composite material made up of soil and high-tensile-strength materials such as steel or

geogrid. Soil alone has no tensile strength, and the reinforcement strengthens the soil by confining it and restricting movement parallel to the reinforcement. Incorporating reinforced soil structures in the development of blast-protective structures can accomplish the following: (1) eliminate the use of heavily reinforced concrete, (2) reduce volume of soil required for construction, (3) reduce the amount of land space required, (4) reduce the construction time, (5) simplify structural repair due to bomb damage as compared to reinforced concrete structures, and (6) reduce initial cost of construction compared to other types of structures.

To design blast-protective structures using reinforced soil, the dynamic response characteristics and analytical theory of reinforced soil subjected to blast loading must be established. Although a substantial amount of research has been performed in the past decade to determine the properties of reinforced soil under static loading condition, little work has been carried out to determine reinforced soil properties or theory under blast loading conditions. Research is therefore required to develop a better understanding of the response of reinforced soil to blast loading. This report represents the first comprehensive research effort conducted to understand the response of reinforced soil wall systems subjected to blast loading.

C. SCOPE

A scope of work was developed to achieve the objectives outlined in Section A. This scope of work includes the following:

- an extensive literature review for evaluation of soil and reinforced soil response to blast loading and availability of soil constitutive models and finite element numerical codes for analyzing reinforced soil systems;

- development of laboratory dynamic soil testing equipment and a laboratory testing program to evaluate dynamic response of a reinforced soil system subjected to blast (i.e.: impulse) loading;

- development and utilization of a numerical simulatio for analysis of reinforced soil wall systems subjected to blast loading; and

- physical modeling of reinforced soil systems subjected to blast loading using centrifuge modeling.

Using this technical approach makes it possible to compare the different analysis techniques and results, provide a quantitative assessment of the properties of reinforced soil and reinforced soil systems subjected to blast loading, and provide preliminary guidelines for selecting appropriate analysis techniques for the design of reinforced soil systems for blast protection.

D. TEST DESCRIPTION

Laboratory testing, numerical modeling and physical modeling was conducted to study the response of reinforced soil structures subjected to blast loading. A brief description of each test is presented below.

Laboratory Tests: Laboratory strength tests were conducted on three types of reinforcing systems: fiber-reinforced sands, geogrid-reinforced sands and steel-reinforced sands. Triaxial tests were conducted on fiber-reinforced sand to estimate the sand's strength properties. Static pullout tests were conducted with both steel and geogrid reinforcement and sands under various confining pressures to characterize the static load-deflection behavior of the reinforced soil. Dynamic pullout tests were then performed using the same parameters as the static tests. A standard static pullout test box was modified to a dynamic load system by installing an impact beam, hydraulic cylinders, springs, and a trigger system. The system was capable of loading the sample in just a few micro-seconds to simulate a blast load. Dynamic load-deflection behavior was characterized and compared to that obtained from static testing.

Numerical Modeling: A numerical model was developed based on the computer code DYNA3D, a non-linear, three -dimensional finite-element code developed by the Lawrence Livermore National Laboratory for use in the analysis of dynamic solid and structural mechanics problems A parametric study was conducted to

observe the influence of several critical factors on the behavior of the reinforced soil wall subjected to blast loading. These factors included reinforcement strength, reinforcement length, weapon size, and weapon location.

Physical Modeling: Nine 1/30th scale model reinforced soil walls were tested in the Air Force Civil Engineering Support Agency (AFCESA) centrifuge at Tyndall Air Force Base, Florida. A parametric study was conducted to observe the influence of several critical factors on the behavior of the model reinforced soil walls subjected to blast loading. These factors included reinforcement length, reinforcement type, reinforcement width, weapon location, and influence of a roof slab on the structure.

E. CONCLUSIONS

A brief summary of results obtained from the laboratory testing, numerical modeling, and physical modeling portions of the study are presented below.

Laboratory Testing Results: Results of triaxial testing on fiber-reinforced sand indicate that soil strength, strain at failure and compressibility increase and stiffness decreases as fiber content increases. Results of the pullout testing indicate that dynamic pullout behavior of geogrid in sand, when measured in terms of load vs. displacement, is very similar under constant normal stress to that observed with standard pullout rates used for static design. The dynamic pullout tests subjected the geogrid to a stress path similar to that caused by blast loading.

Numerical Modeling Results: Results of the numerical modeling program indicate that soil stiffness and friction angle significantly affect was performance, as does reinforcement stiffness. Reinforcement length and soil/reinforcement interface friction coefficient are relatively less important parameters, provided they are kept within normal ranges for static stability.

Physical Modeling: Results of the physical modeling tests indicate that reinforcement type and width play a significant role in wall behavior. The importance of a horizontal constraint along the top of the wall (i.e., a roof

slab) has also been demonstrated. Reproducibility of test results and similarity to numerical predictions provide evidence of the appropriateness of the centrifuge modeling technique for this problem.

F.   RECOMMENDATIONS

The results of limited laboratory, centrifuge modeling, and numerical modeling tests conducted in this study indicate that statically designed reinforced soil structures perform favorably as blast-protective structures. It is recommended that the Air Force pursue a more comprehensive study of the use of reinforced soil structures for blast protection with the ultimate goal of developing design procedures and design drawings for reinforced soil structures. This study should include full-scale testing, a comprehensive series of centrifuge tests, modifications to the numerical model, and comprehensive numerical modeling of the centrifuge tests. Ultimately, studies should be developed that investigate other weapons effects on reinforced soil structures such as airblasts and projectile penetrations.

PREFACE

This report was prepared by GeoSyntec Consultants, 5775 Peachtree Dunwoody Road, Suite 200F, Atlanta, Georgia 30342 under Contractor Number F08635-90-C-0198 for the Air Force Civil Engineering Support Agency (AFCESA), Civil Engineering Laboratory, 139 Barnes Drive, Tyndall Air Force Base, Florida 32403-6001.
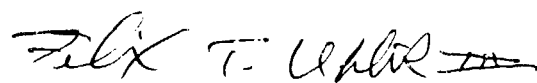
This report summarizes work accomplished between 8 June 1990 and 30 June 1992. Captain Richard A. Reid, USAF, was the AFCESA/RACS technical program manager.

This report has been reviewed by the Public Affairs Office and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication.

RICHARD A. REID, Capt, USAF
Project Officer

FELIX T. UHLIK III, Lt Col, USAF
Chief, Engineering Research
Division

WILLIAM S. STRICKLAND, GM-14
Chief, Air Base Survivability
Branch

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APPENDIX A

LABORATORY TESTING

A. INTRODUCTION

This appendix contains plots of laboratory test results. The appendix is organized as follows:

- Part B presents results from direct shear tests on the SP and SW-SM sands.

- Part C presents the results of static pullout tests on geogrids and galvanized earth bars.

- Part D presents a verification of the numerical integration method used to determine dynamic displacement-time histories for pullout tests.

- Part E contains results of dynamic tensile tests.

- Part F contains results of dynamic pullout tests.

B. DIRECT-SHEAR TESTS

Figures 1 and 2 present the results of direct-shear tests conducted on the SP and SW-SM sands, respectively.
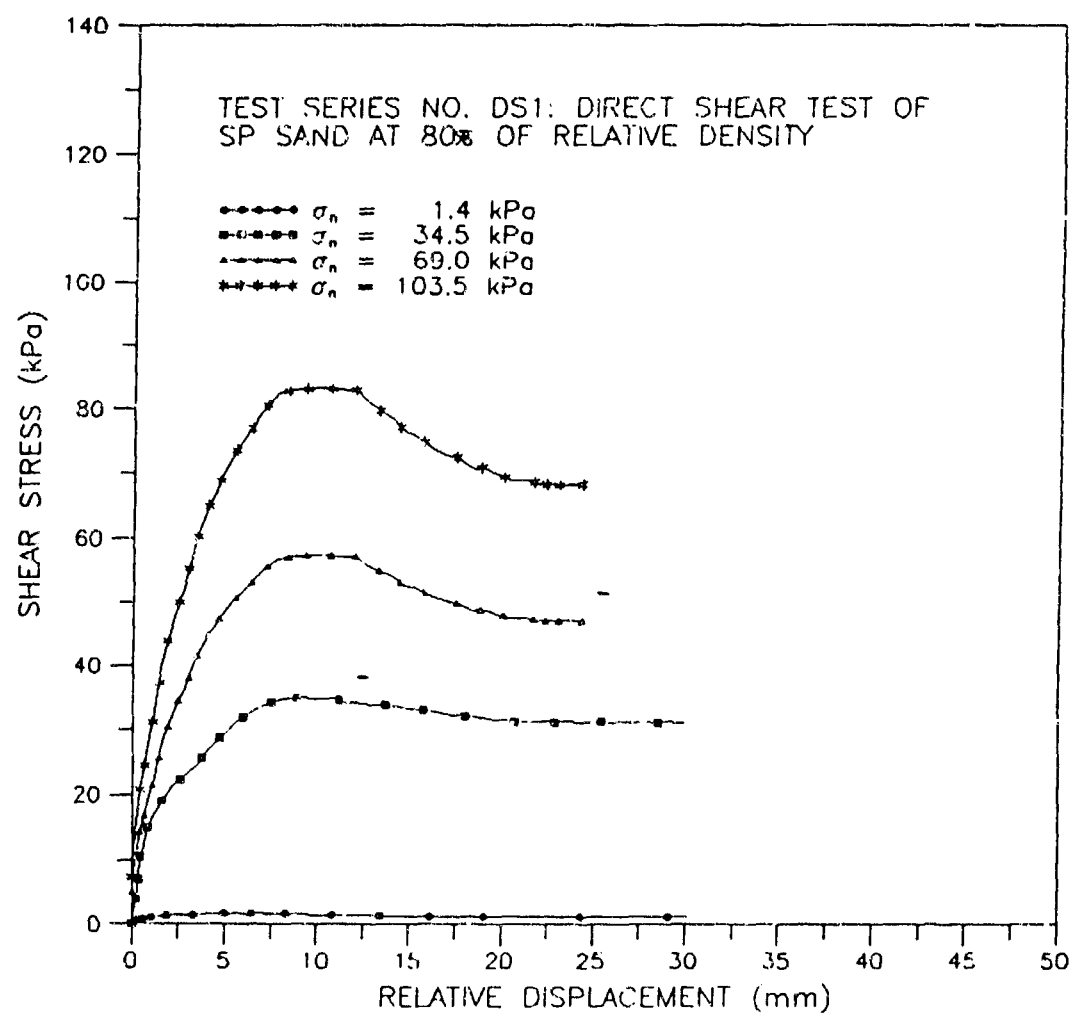
Figure 1. Direct-Shear Test Results on SP Sand.

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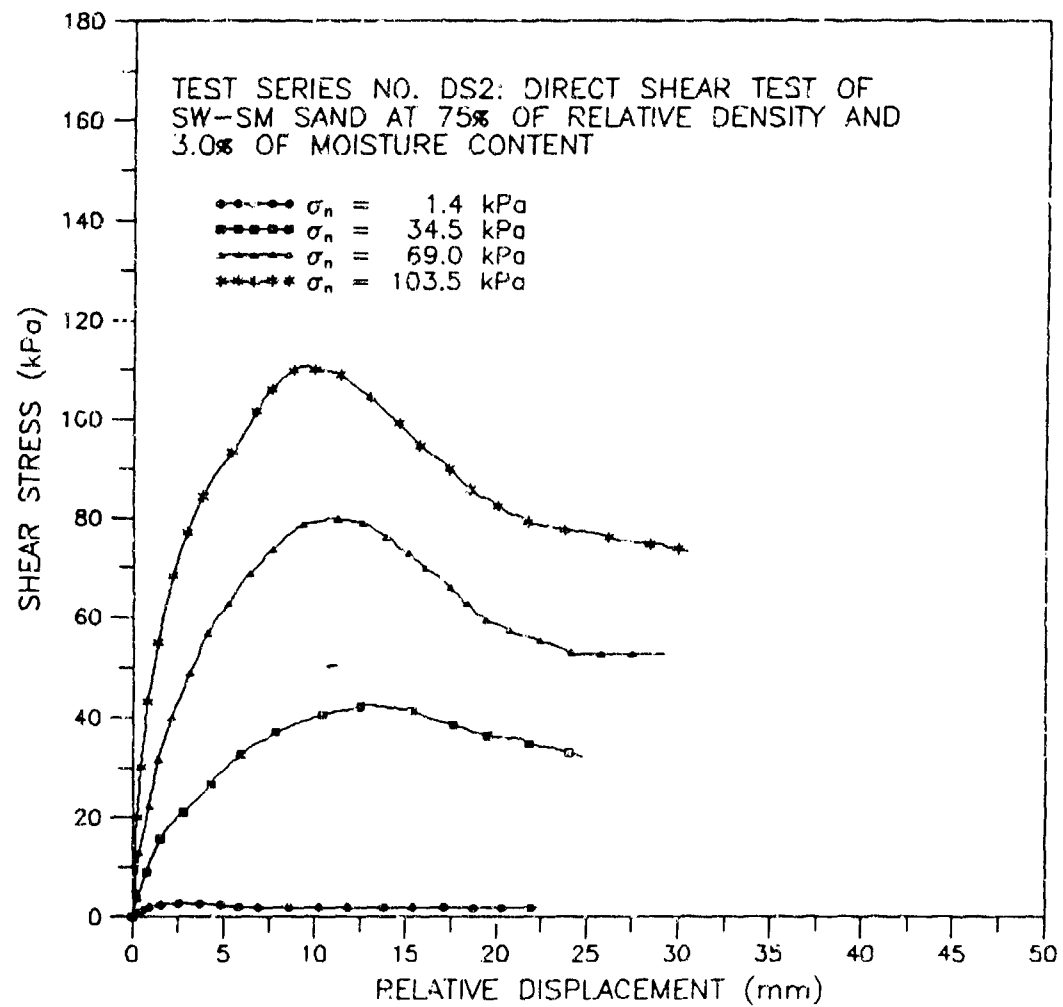
Figure 2. Direct-Shear Test Results on SW SM Sand.

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C. STATIC PULLOUT TESTS

Figures 3 - 10 present the results of static pullout tests on Miragrid 10T, Matrex 120 and Tensar UX1500 geogrid, and galvanized earth bars in S^p sand.

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TEST NO. 2: MIRAGRID 10T GEOGRID IN SP SAND

σ_n = 2.1 kPa; Dr = 80; Rate = 1 mm/min
σ_n = 22.8 kPa; Dr = 80; Rate = 1 mm/min
σ_n = 36.6 kPa; Dr = 80; Rate = 1 mm/min
σ_n = 71.1 kPa; Dr = 80; Rate = 1 mm/min
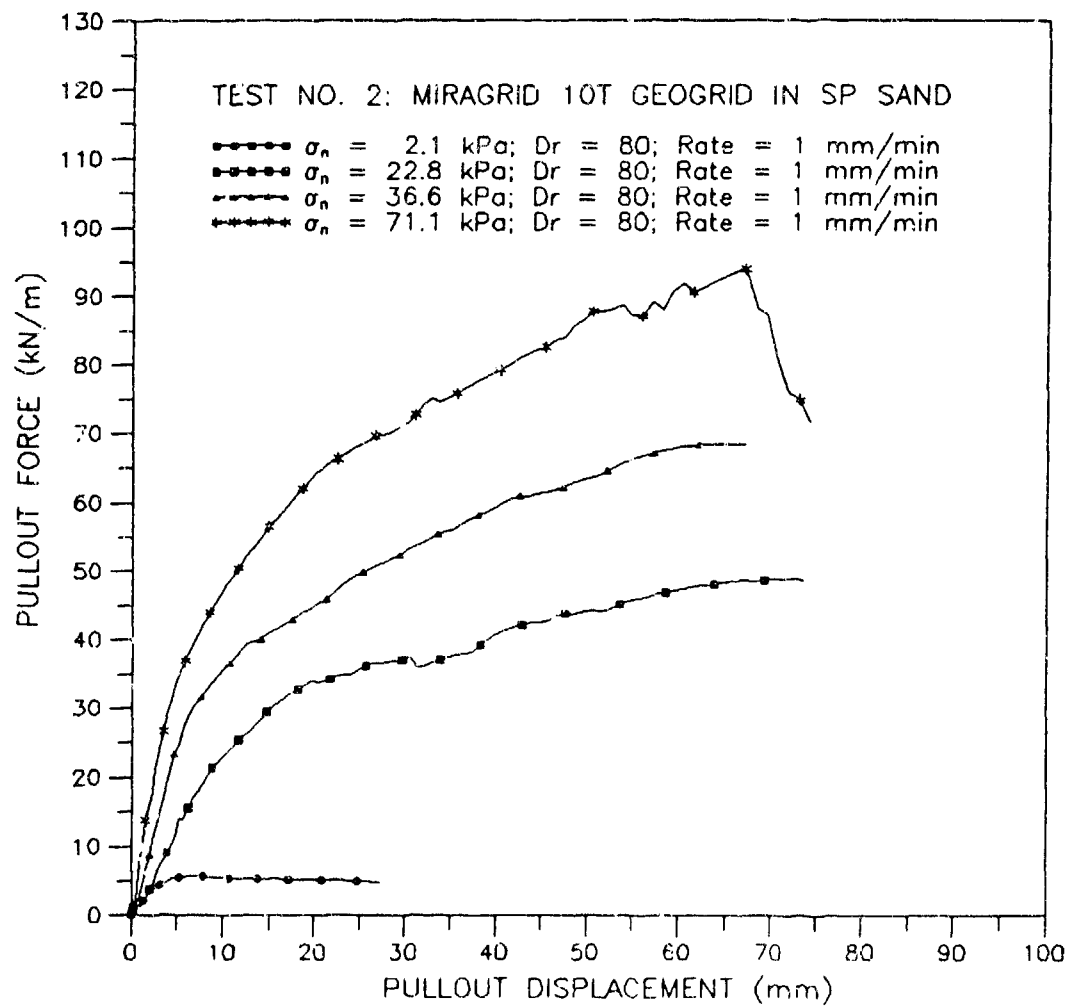
Figure 3. Pullout Responses of Miragrid 10T Geogrid in SP Sand.

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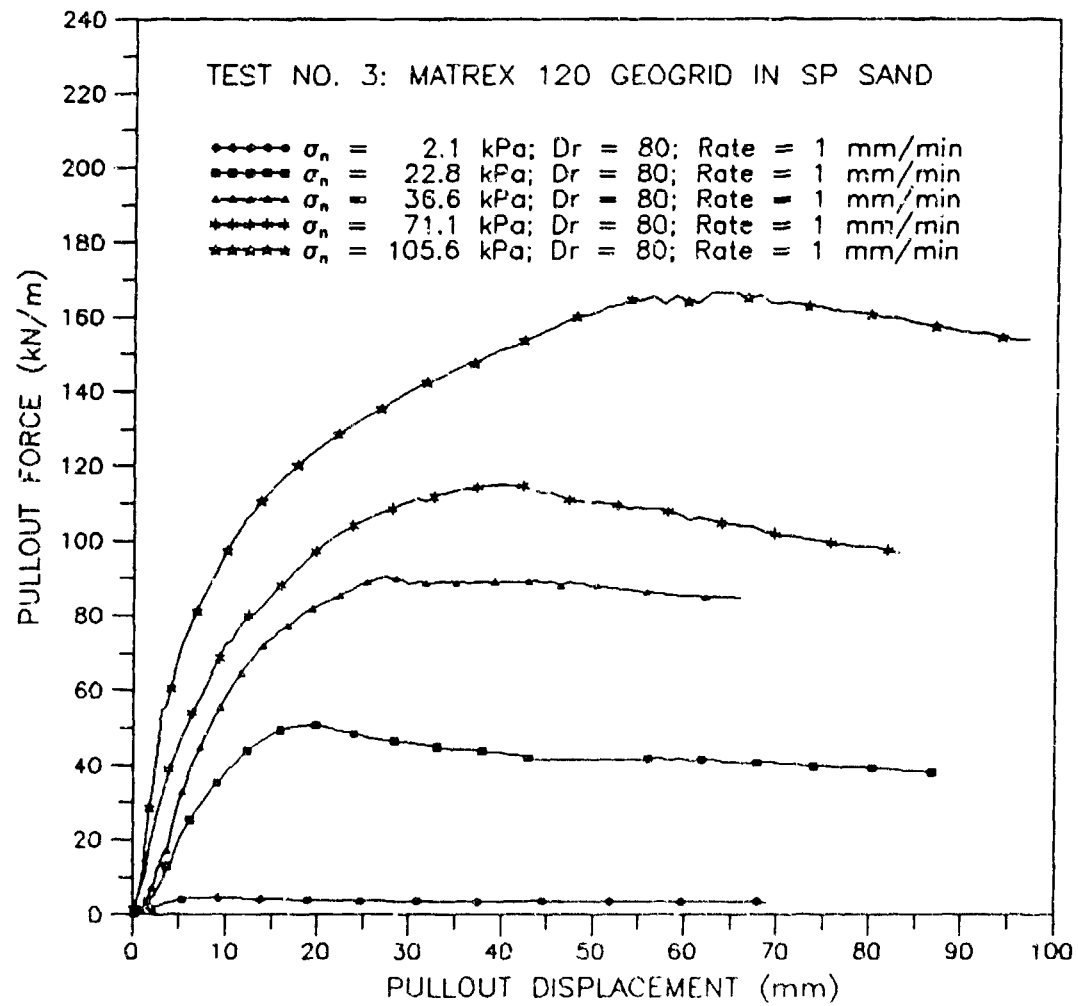
Figure 4. Pullout Responses of Matrex 120 Geogrid in SP Sand.

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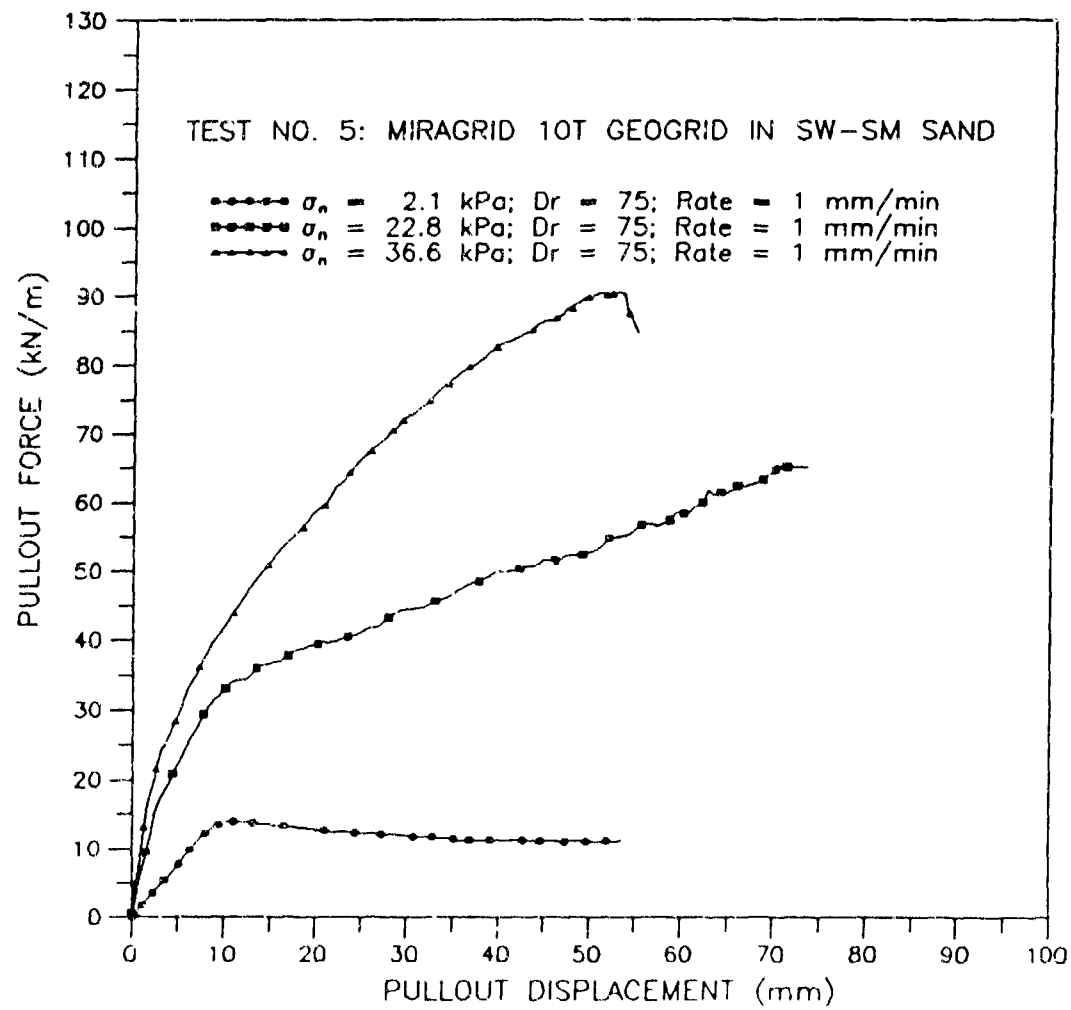
Figure 5. Pullout Responses of Miragrid 10T Geogrid in SW-SM Sand.

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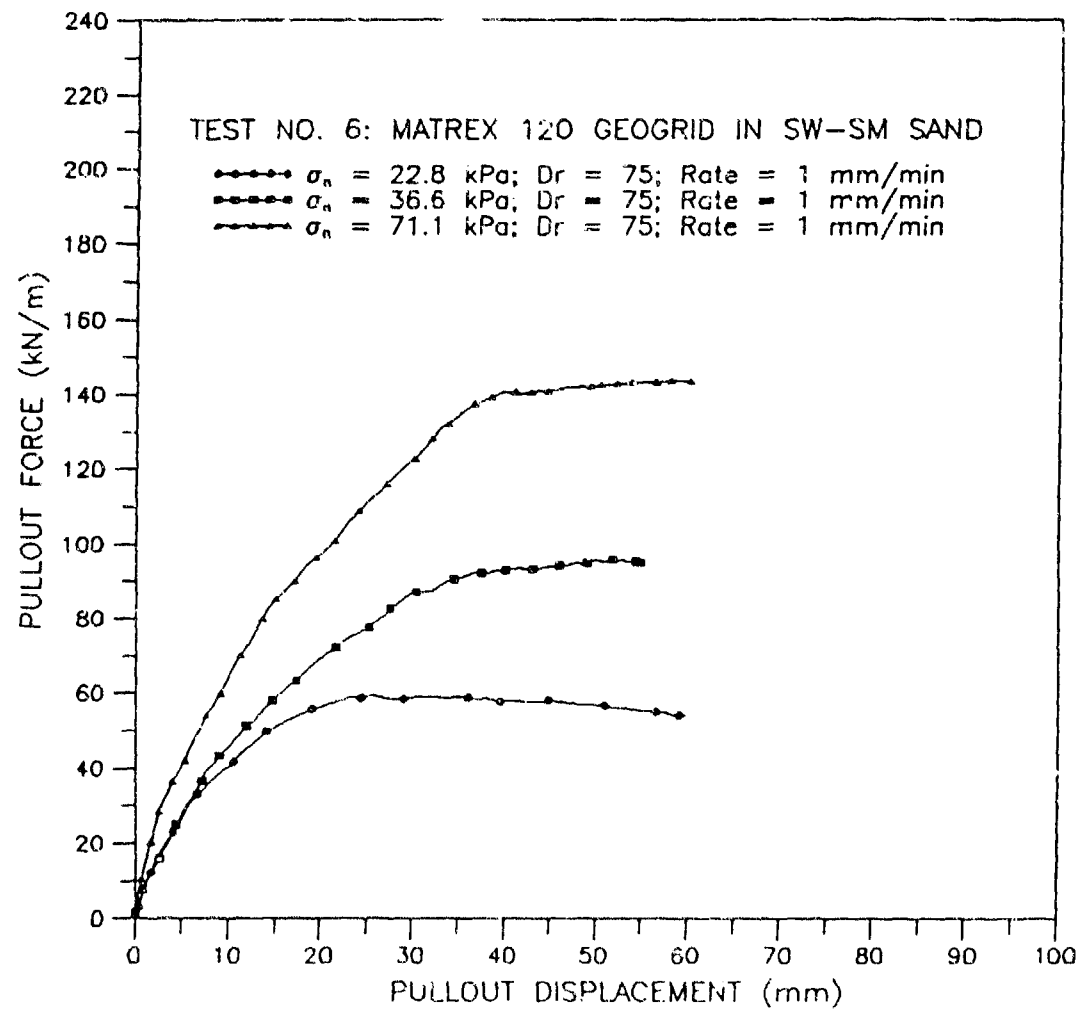
Figure 6. Pullout Responses of Matrex 120 Geogrid in SW-SM Sand.

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TEST NO. 7: TENSAR UX1500 GEOGRID IN SP SAND

σ_n = 2.1 kPa; Dr = 80; Rate = 152 mm/min
σ_n = 22.8 kPa; Dr = 80; Rate = 152 mm/min
σ_n = 36.6 kPa; Dr = 80; Rate = 152 mm/min
σ_n = 71.1 kPa; Dr = 80; Rate = 152 mm/min
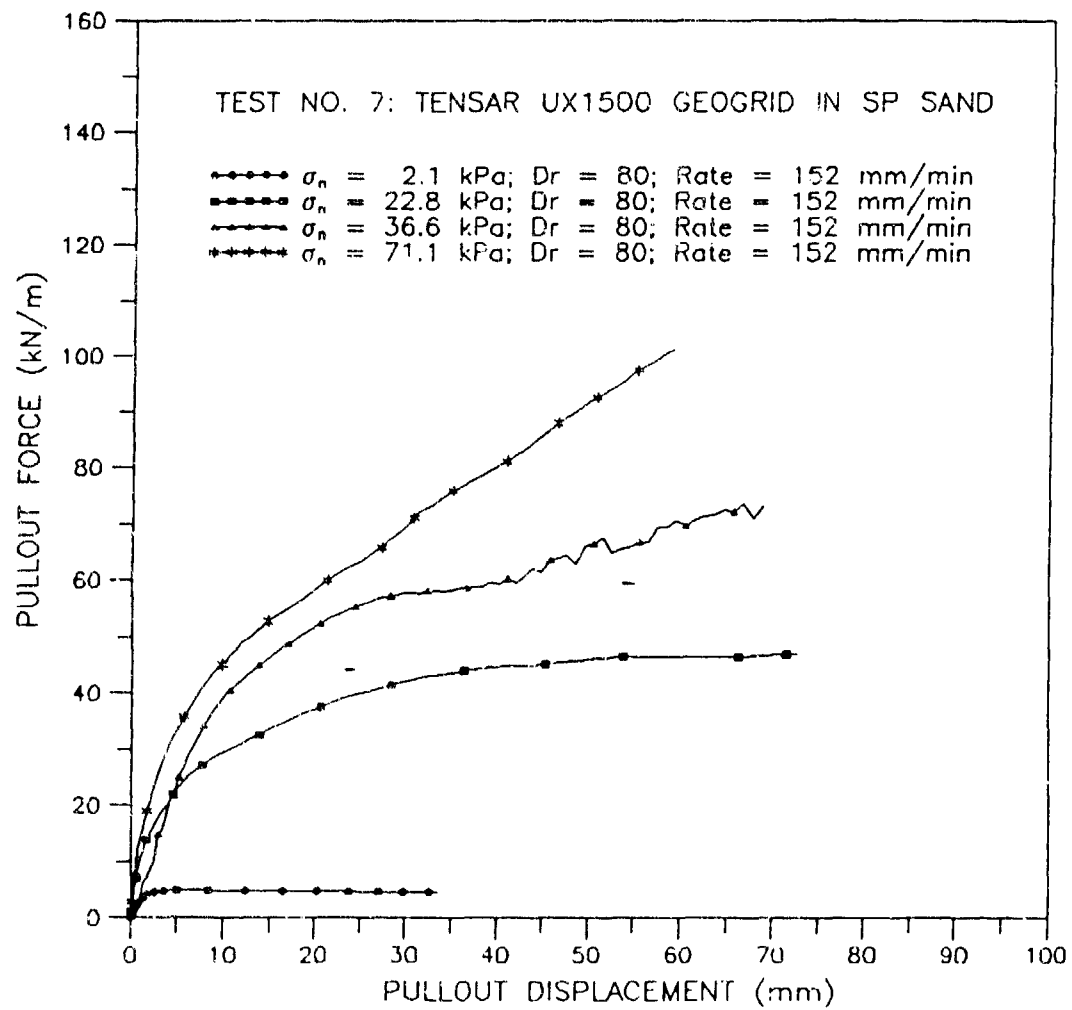
Figure 7.   Pullout Responses of Tensar UX1500 Geogrid in SP Sand.

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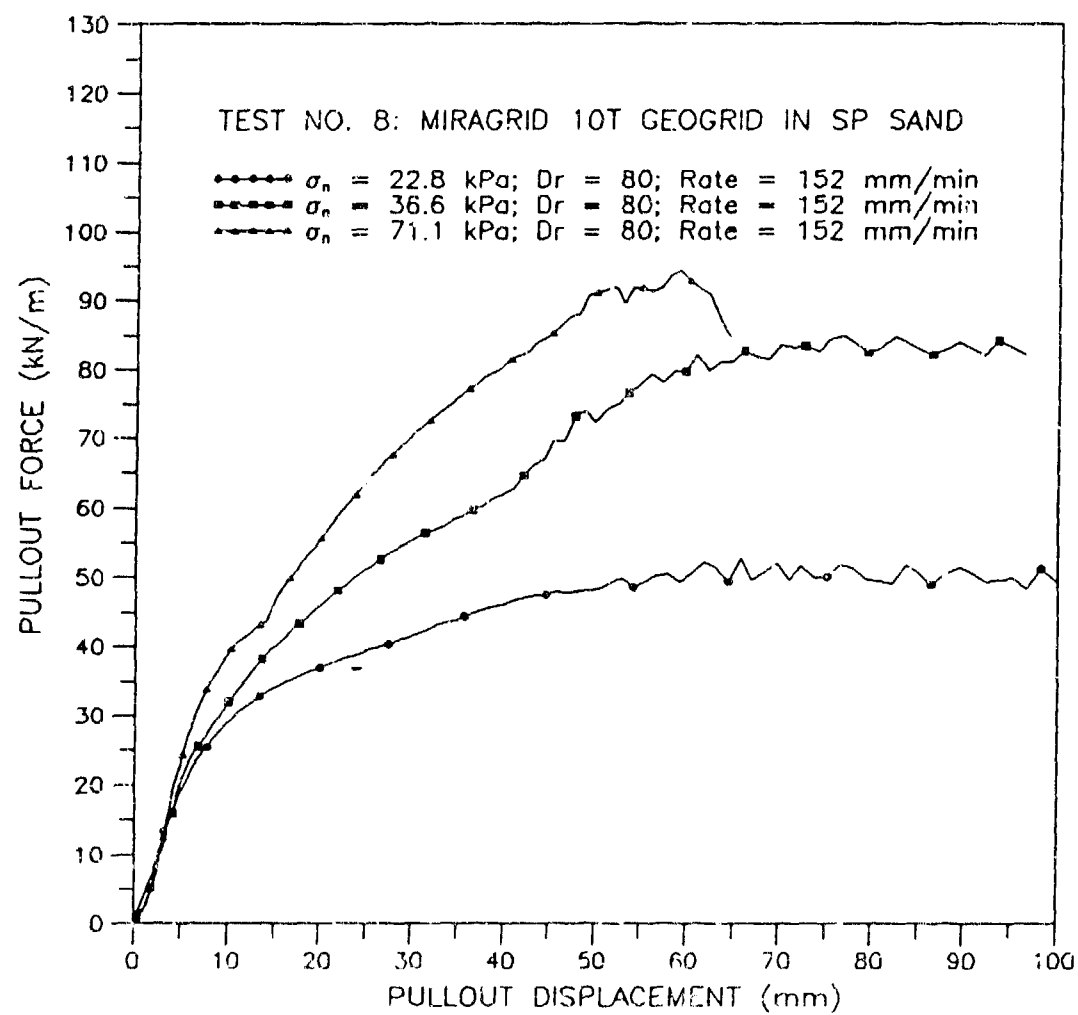
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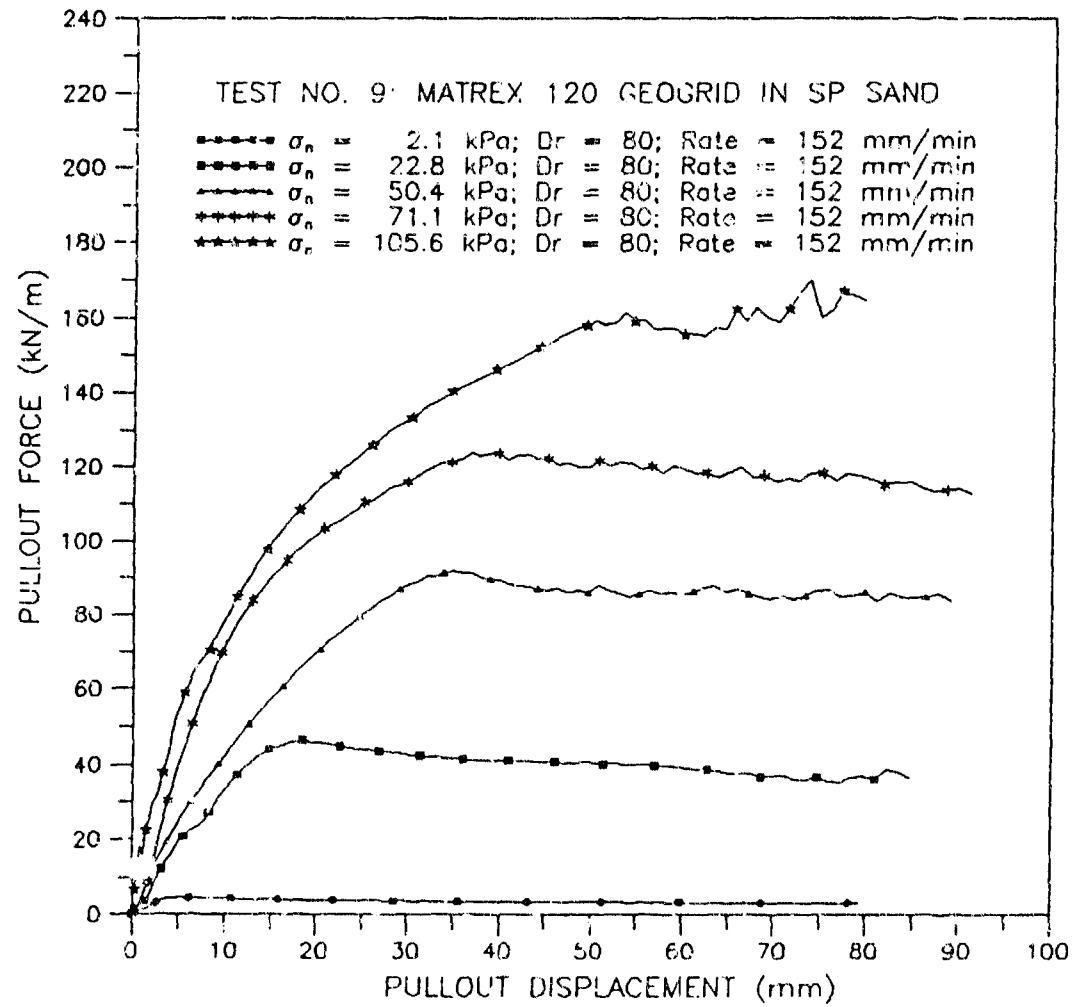
Figure 9. Pullout Responses of Matrex 120 Geogrid in SP Sand.

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TEST NO. 10: GALVANIZED EARTH BAR IN SP SAND

$\sigma_n = 2.1$ kPa; Dr = 80; Rate = 1 mm/min
$\sigma_n = 36.6$ kPa; Dr = 80; Rate = 1 mm/min
$\sigma_n = 71.1$ kPa; Dr = 80; Rate = 1 mm/min
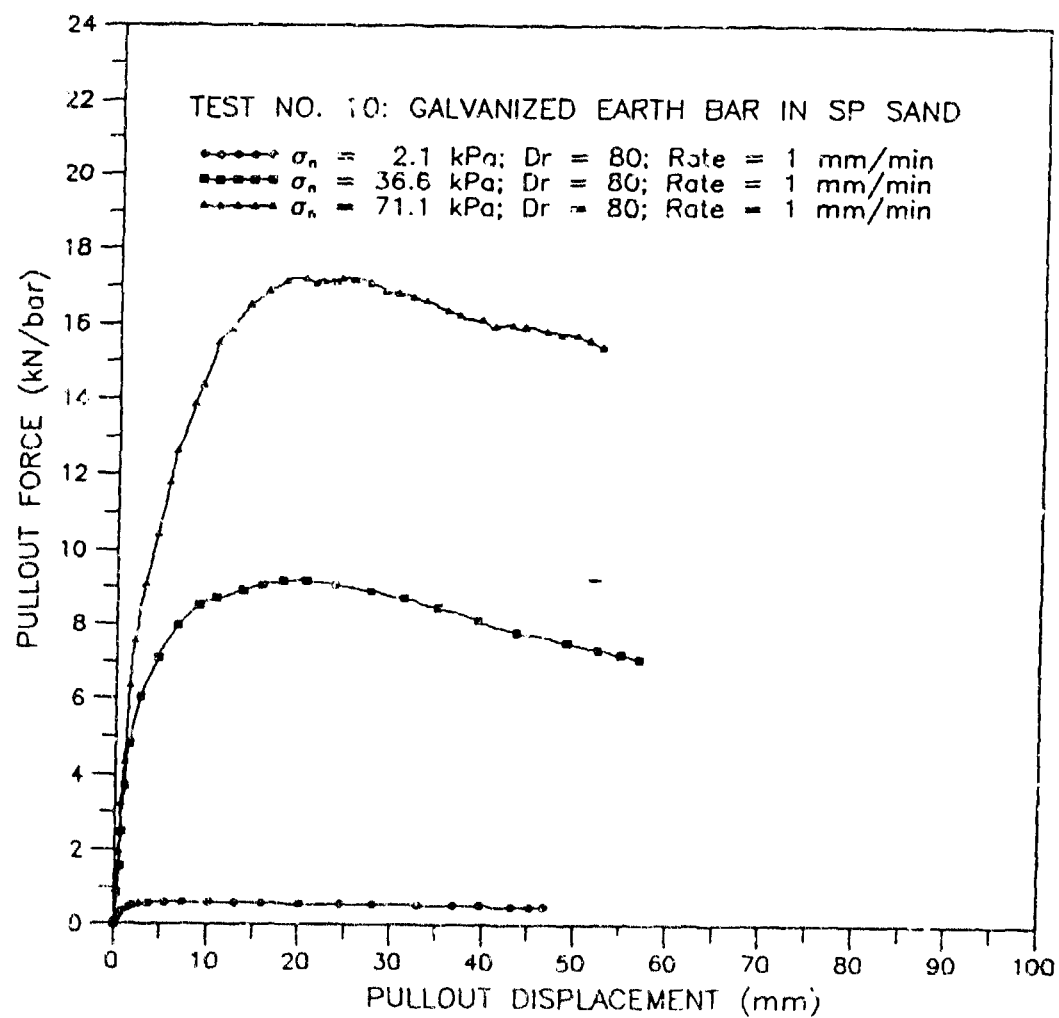
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D. VERIFICATION OF THE NUMERICAL INTEGRATION METHOD

Figure 11 presents the assumed velocity-time history used to validate the numerical integration method utilized for calculation of dynamic displacement-time histories. Figure 12 presents a comparison of numerical and closed-form integration of this velocity-time history.
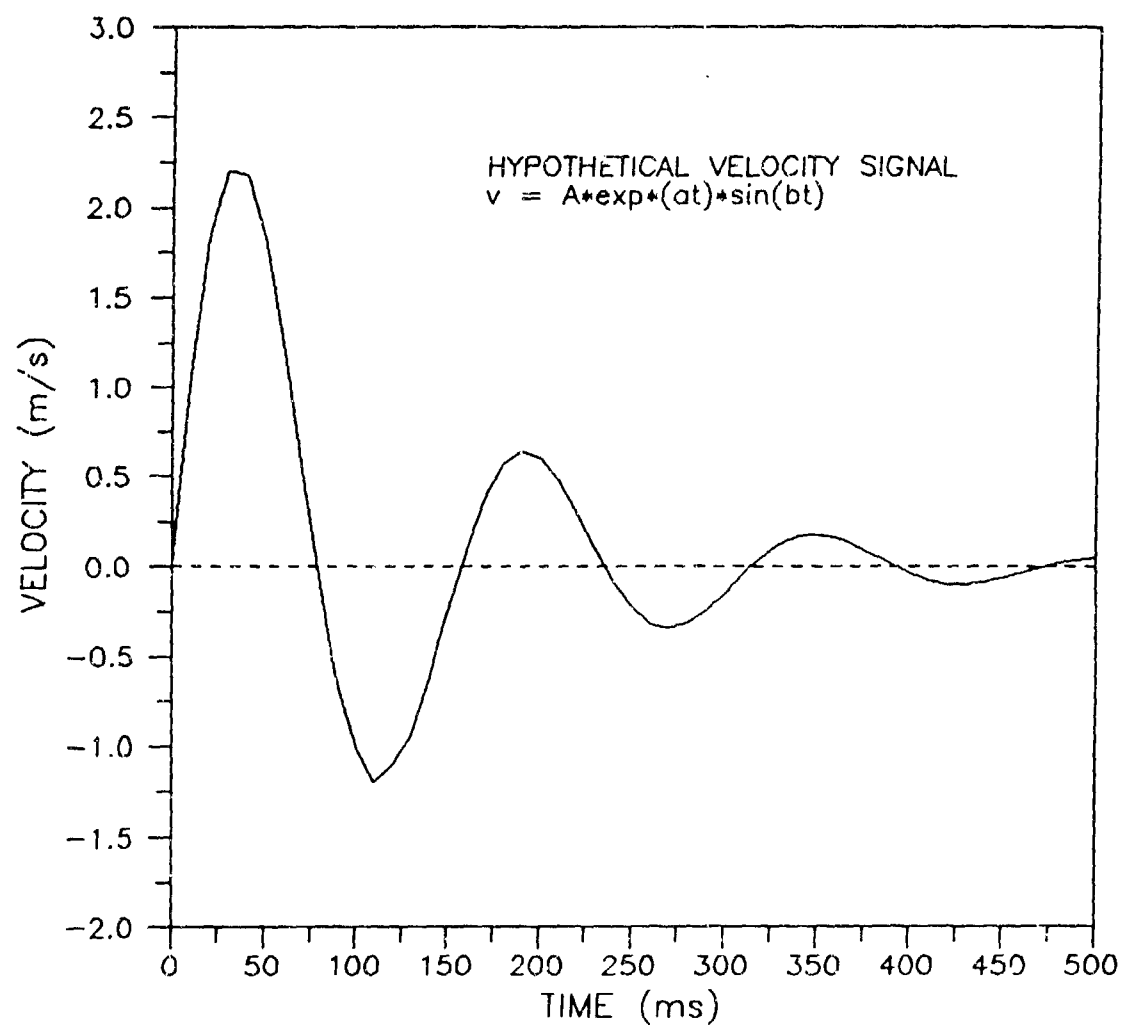
Figure 11. A Hypothetical Velocity Time History.
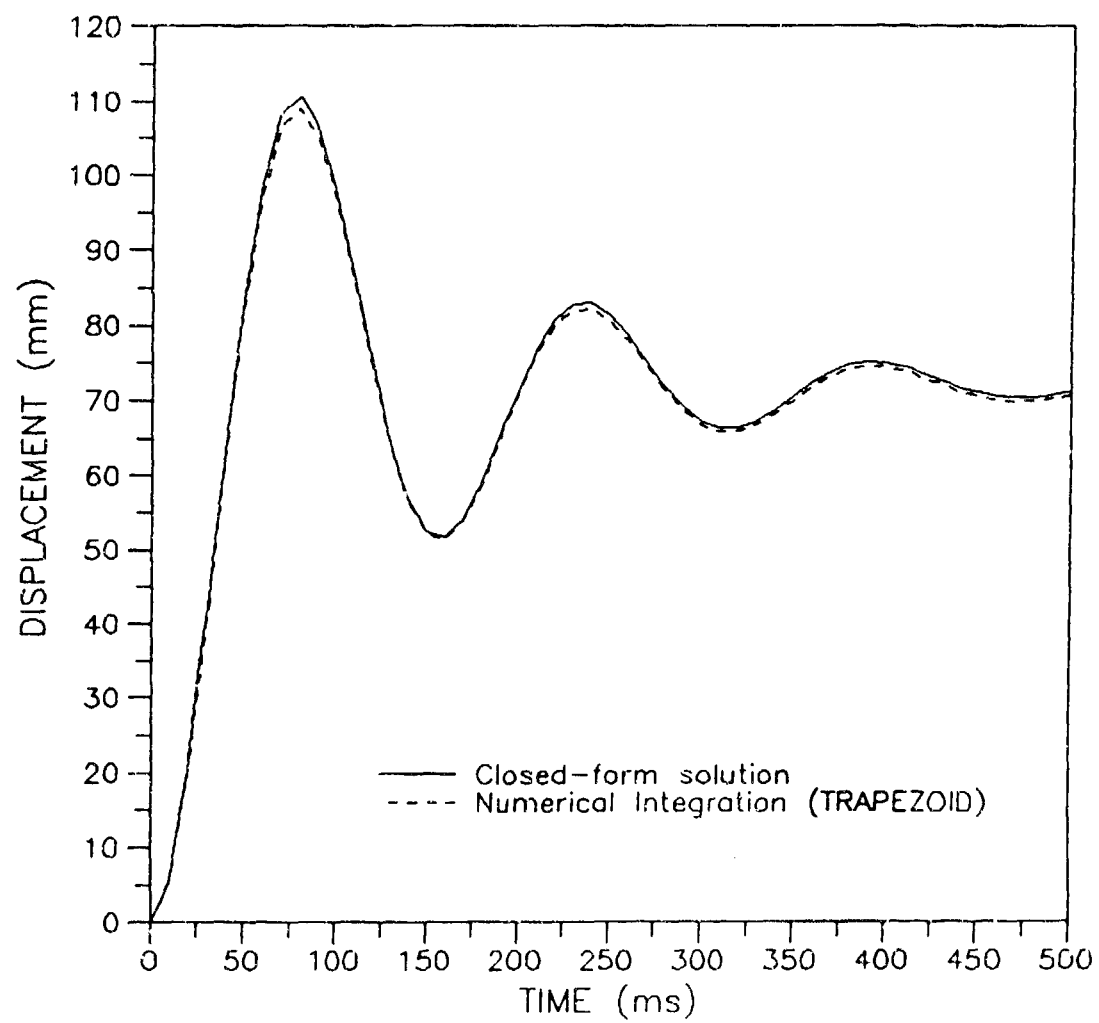
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E. DYNAMIC TENSILE TESTS

Figures 13 - 24 present the results of dynamic tensile tests on Miragrid 10T, Matrex 120 and Tensar UX1500 geogrid.

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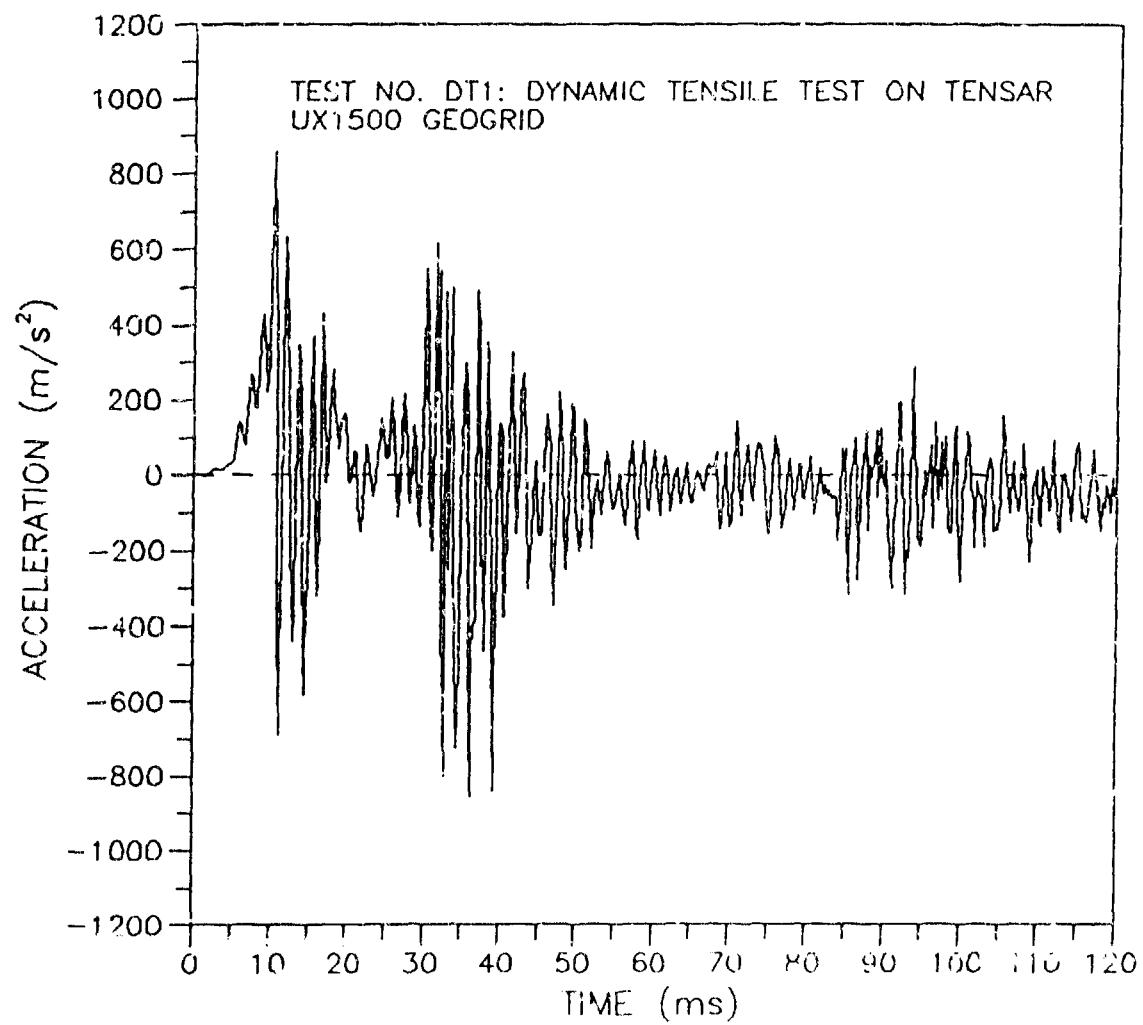
Figure 13. Measured Acceleration at Pulling End of Tensar UX1500 Geogrid for Test DT1.

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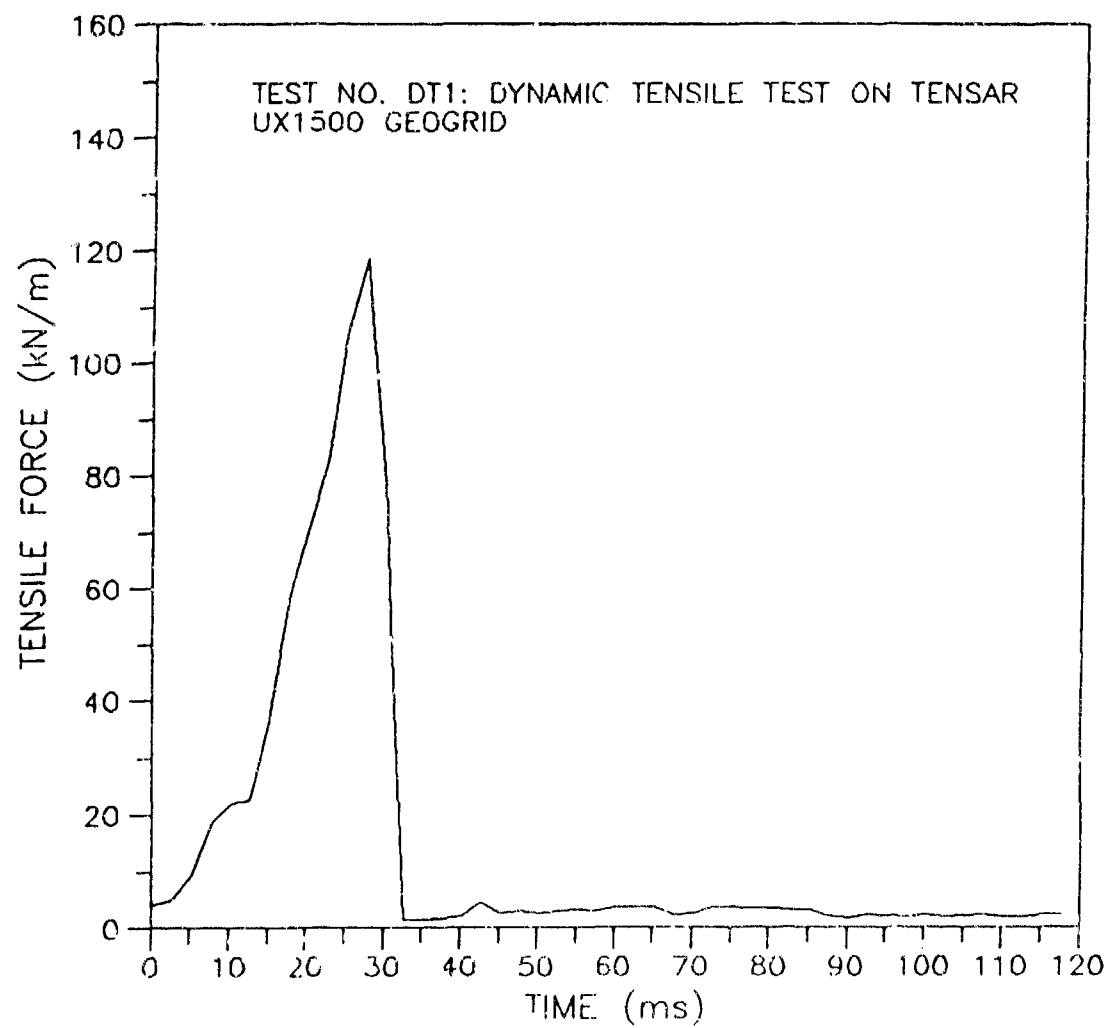
Figure 14.   Measured Force at Pulling End of Tensar UX1500 Geogrid for Test DT1.

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TEST NO. DT1: DYNAMIC TENSILE TEST ON TENSAR
UX1500 GEOGRID
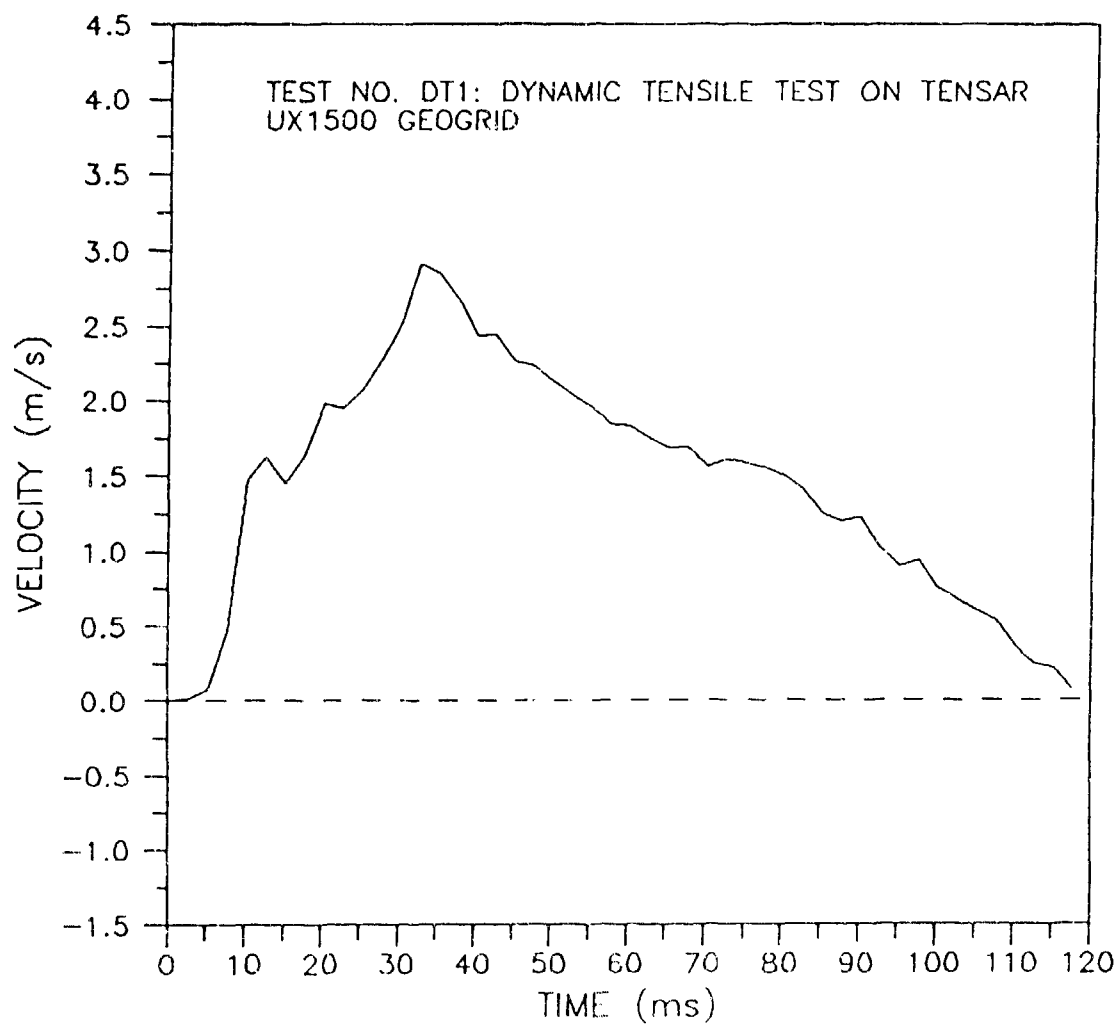
Figure 15.   Velocity Time History at Pulling End of Tensar UX1500
Geogrid for Test DT1.

TEST NO. DT1: DYNAMIC TENSILE TEST ON TENSAR
UX1500 GEOGRID
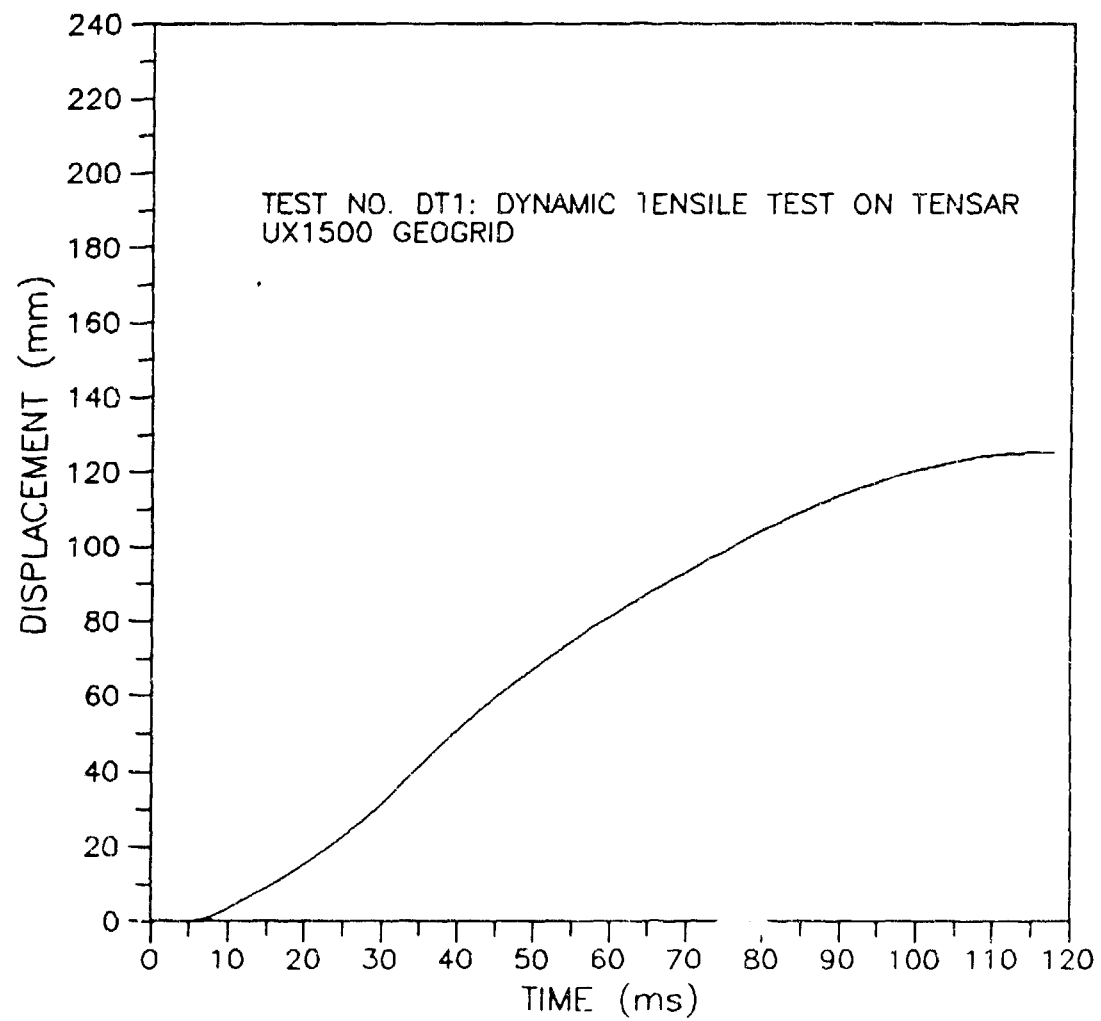
Figure 16. Displacement Time History at Pulling End of Tensar
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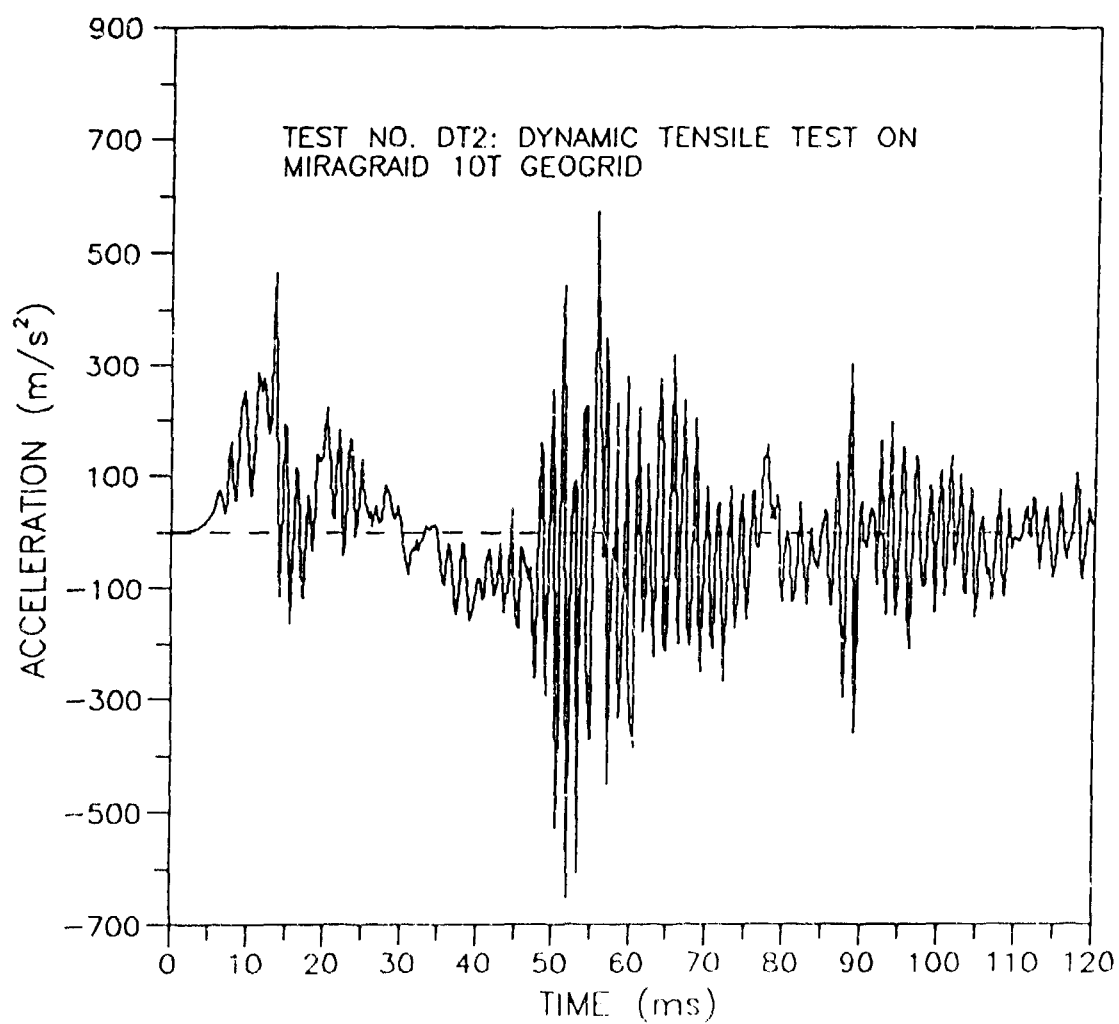
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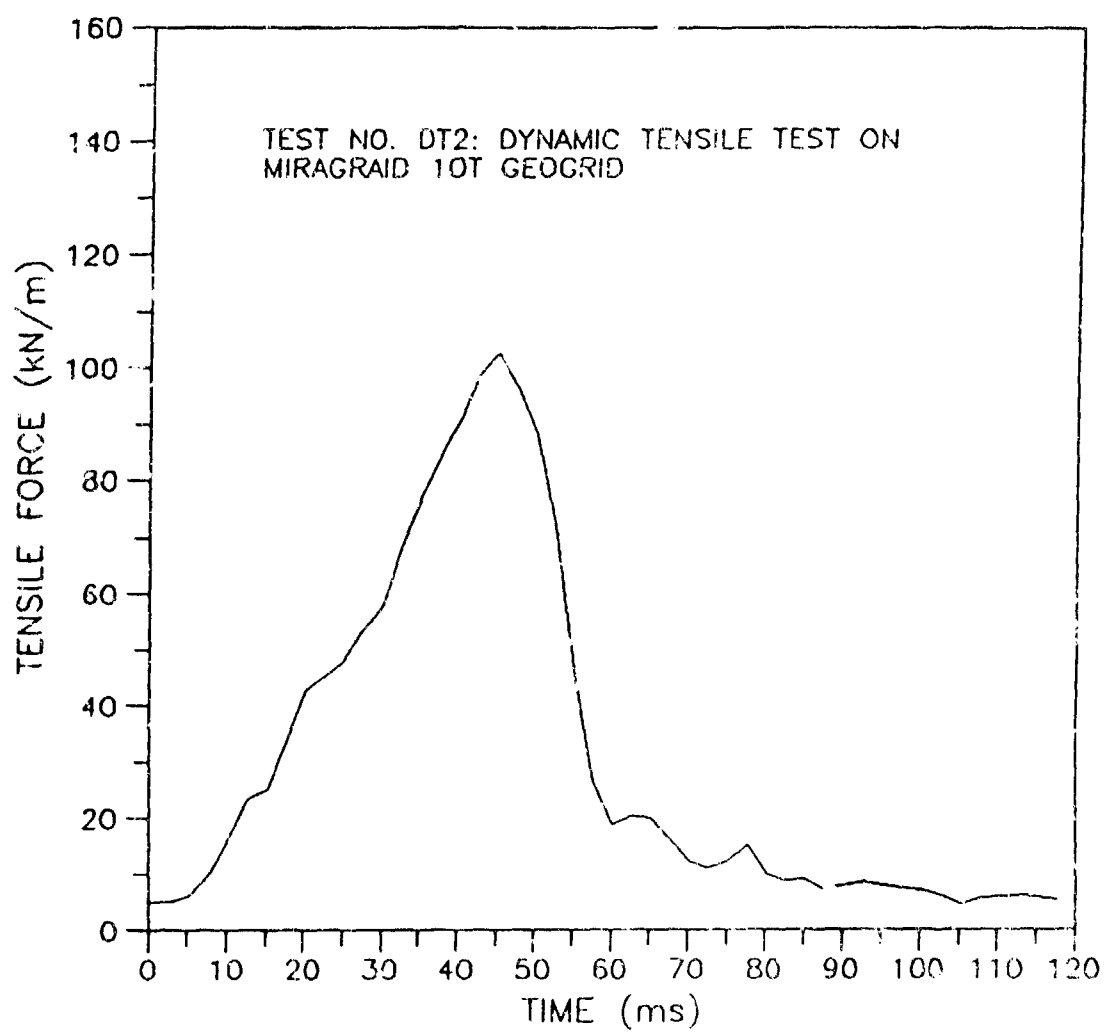
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TEST NO. DT2: DYNAMIC TENSILE TEST ON MIRAGRAID 10T GEOGRID

Figure 16. Measured Force at Pulling End of Miragrid 10T Geogrid for Test DT2.

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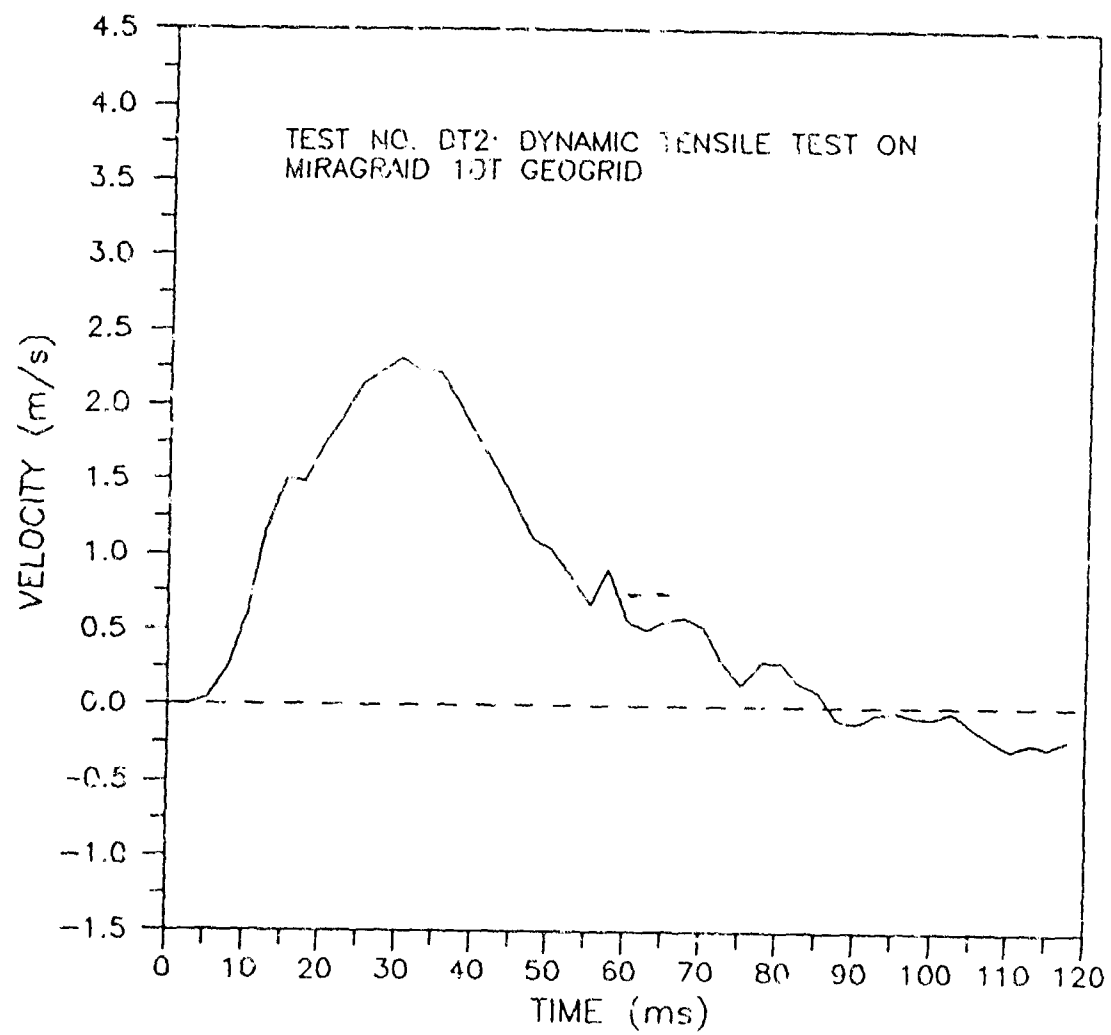
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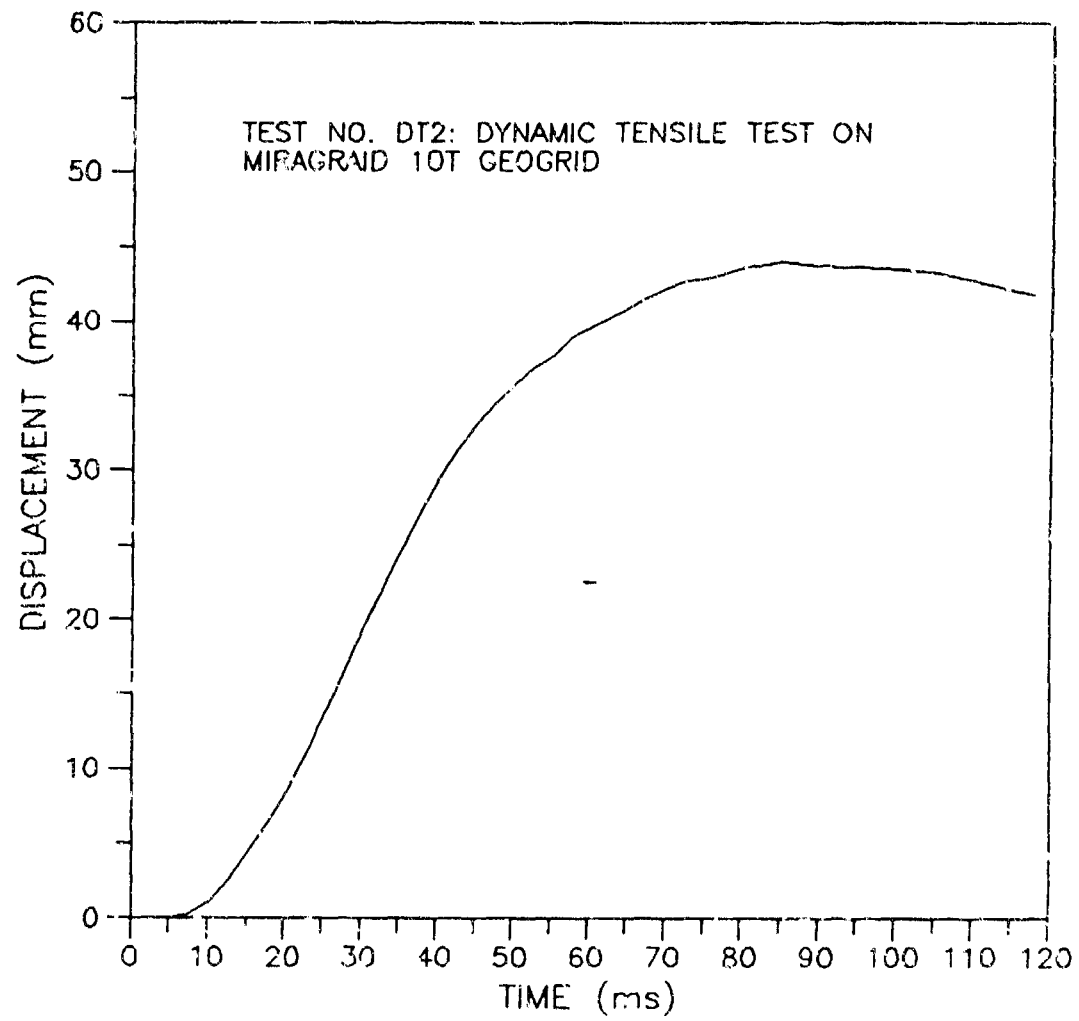
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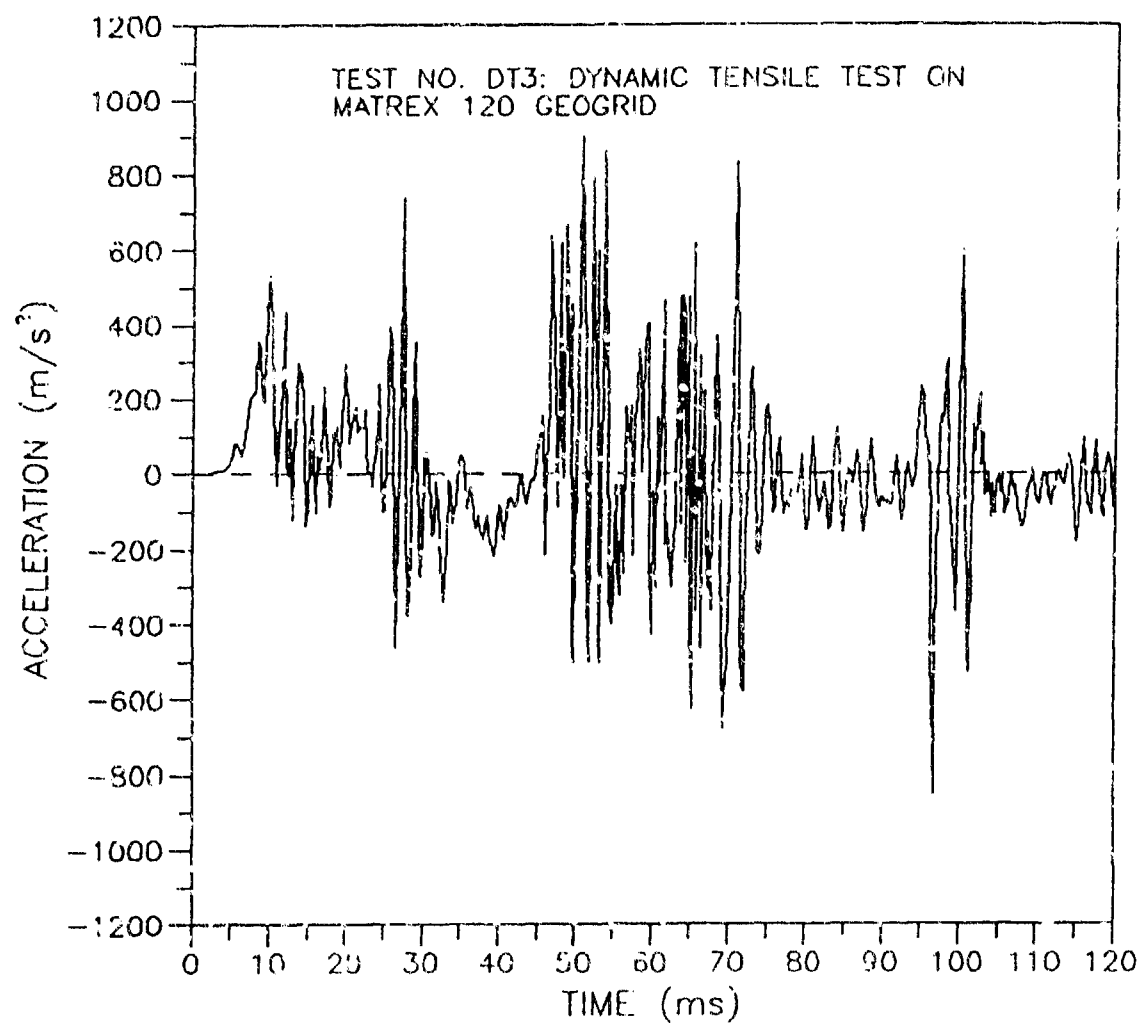
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TEST NO. DT3: DYNAMIC TENSILE TEST ON
MATREX 120 GEOGRID
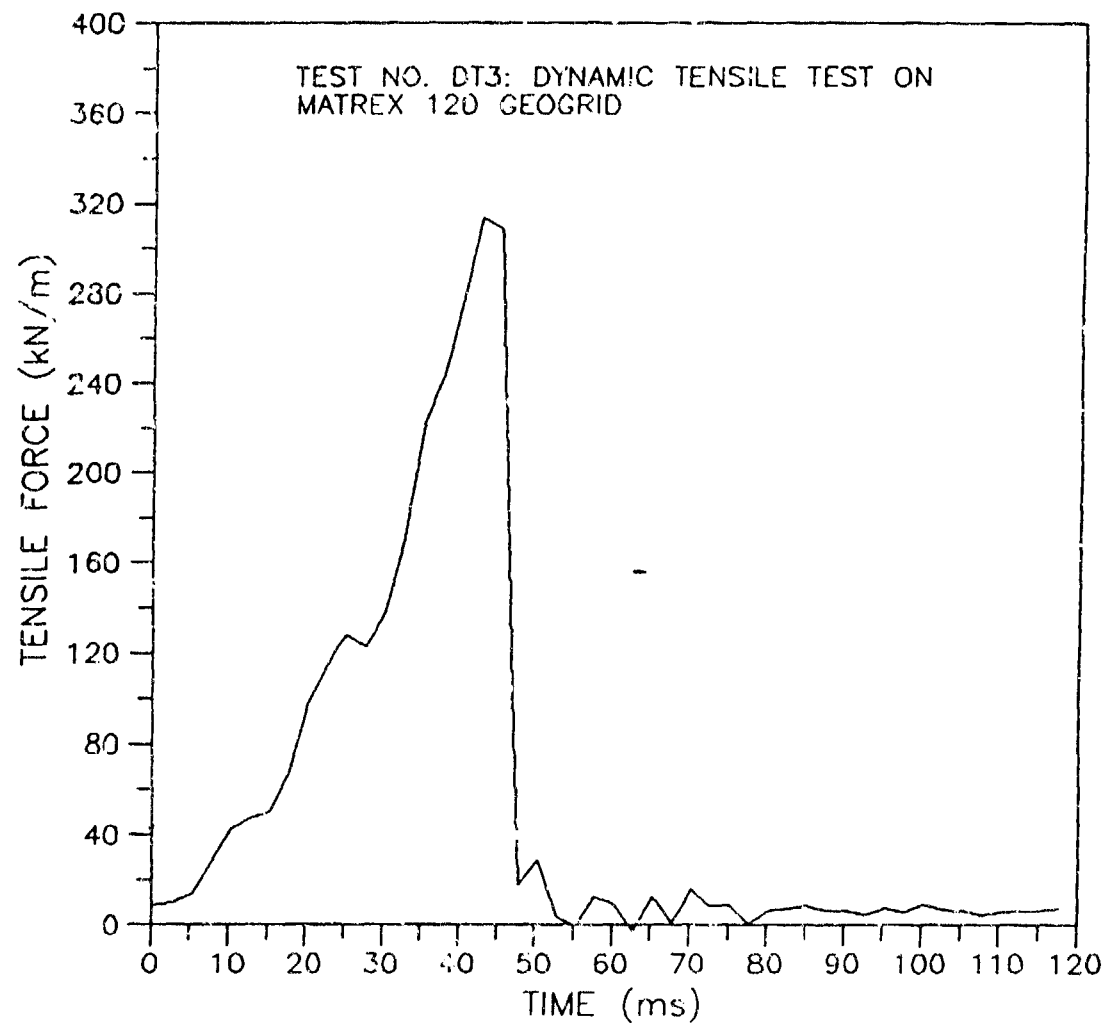
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for Test DT3.

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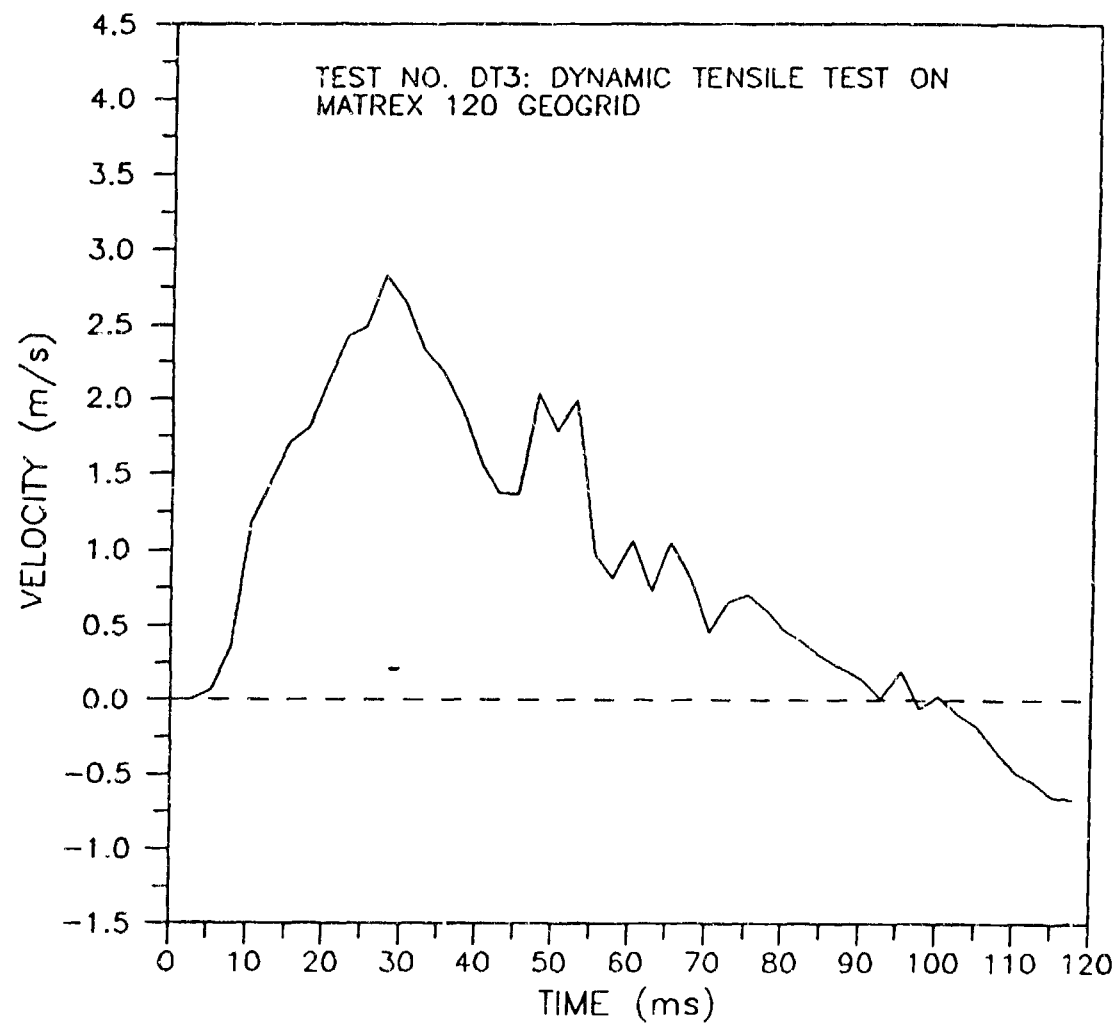
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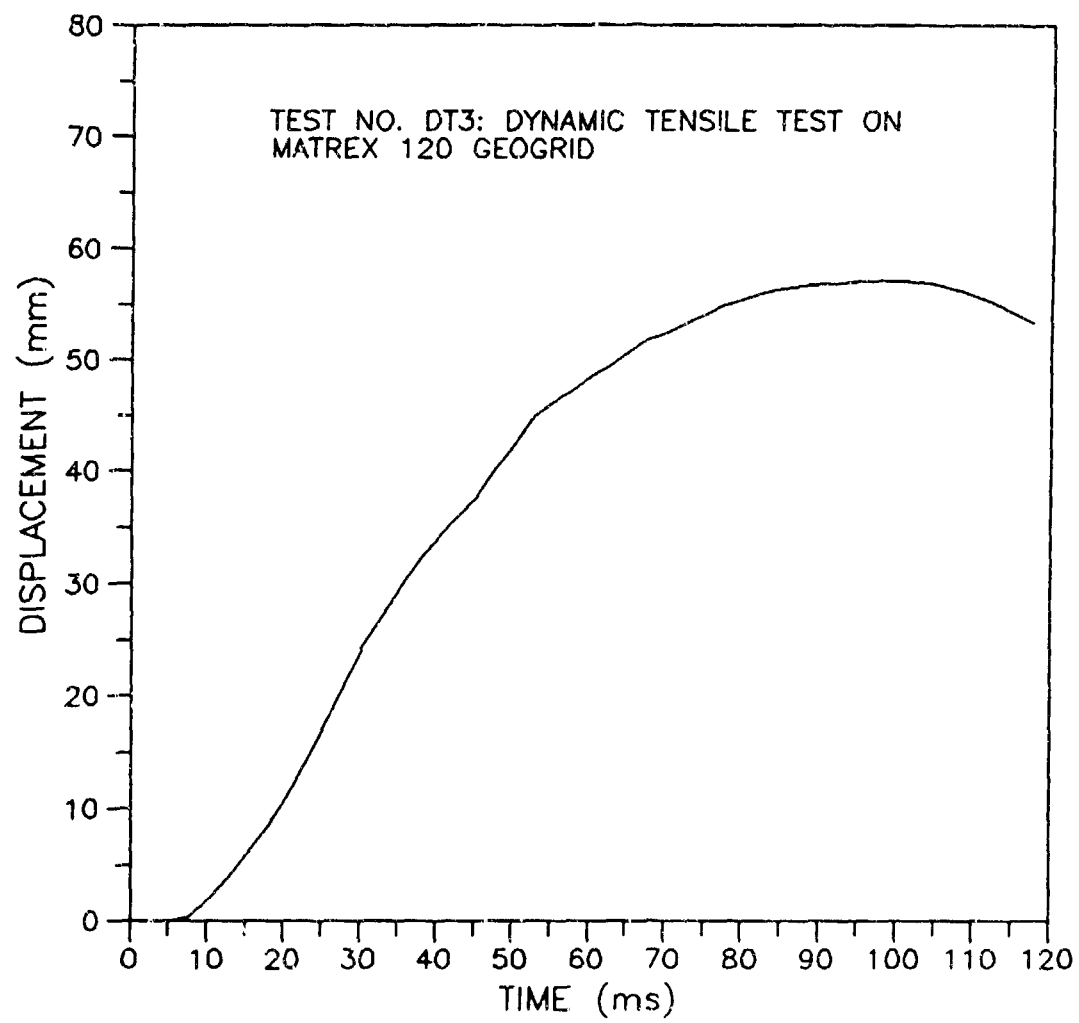
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F. DYNAMIC PULLOUT TESTS

Figures 25 - 92 present the results of all dynamic pullout tests conducted on Miragrid 10T, Matrix 120 and Tensar UX1500 geogrid.

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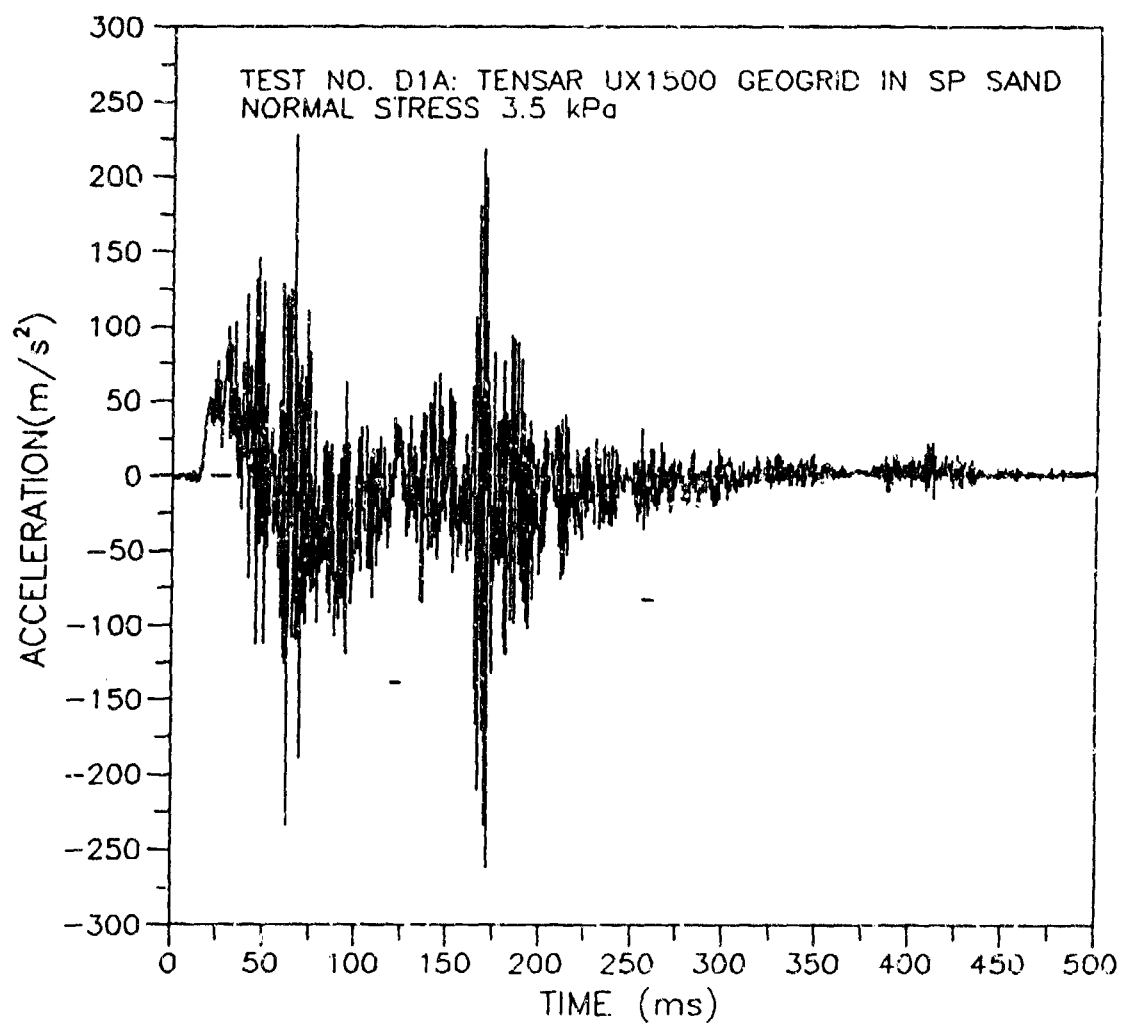
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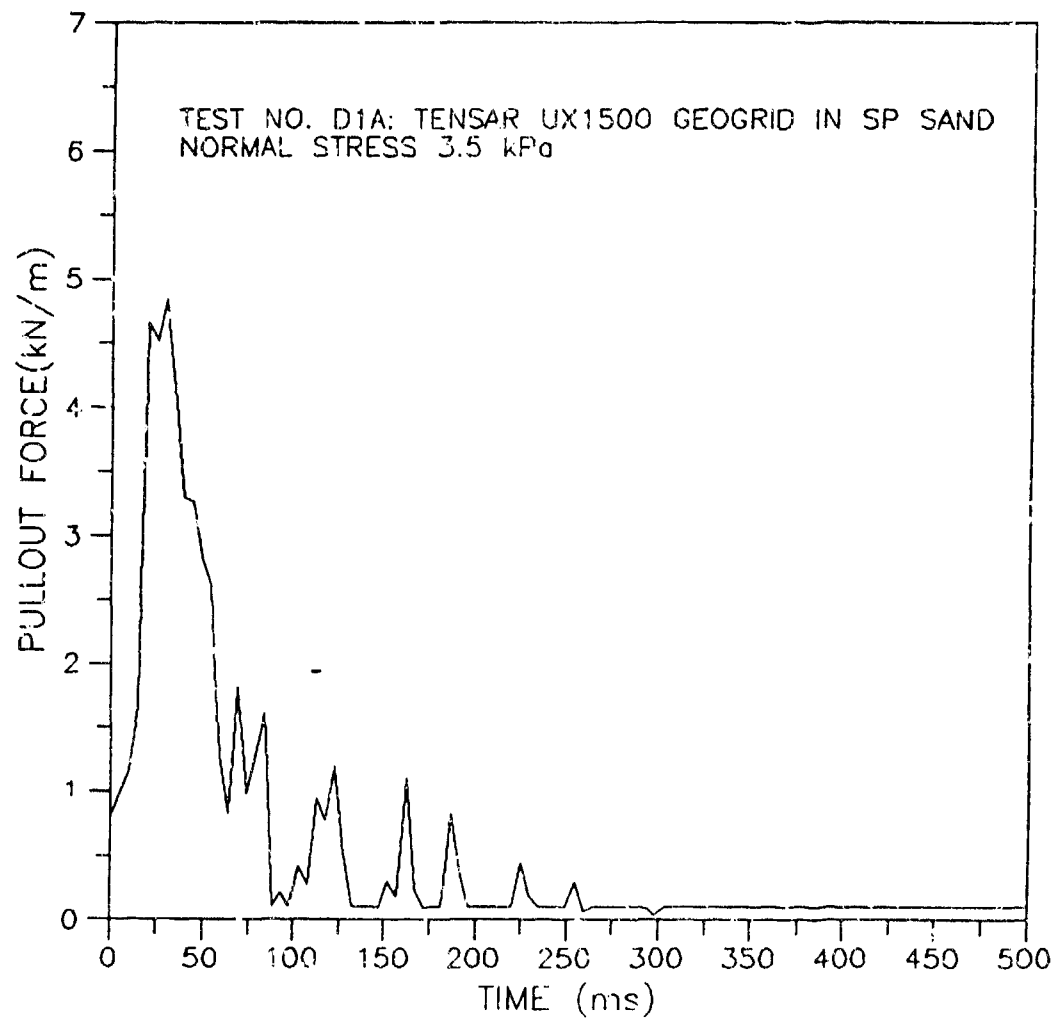
Figure 26. Measured Force at Pulling End of Tensar UX1500 Geogrid for Test D1A.

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TEST NO. D1A: TENSAR UX1500 GEOGRID IN SP SAND
NORMAL STRESS 3.5 kPa
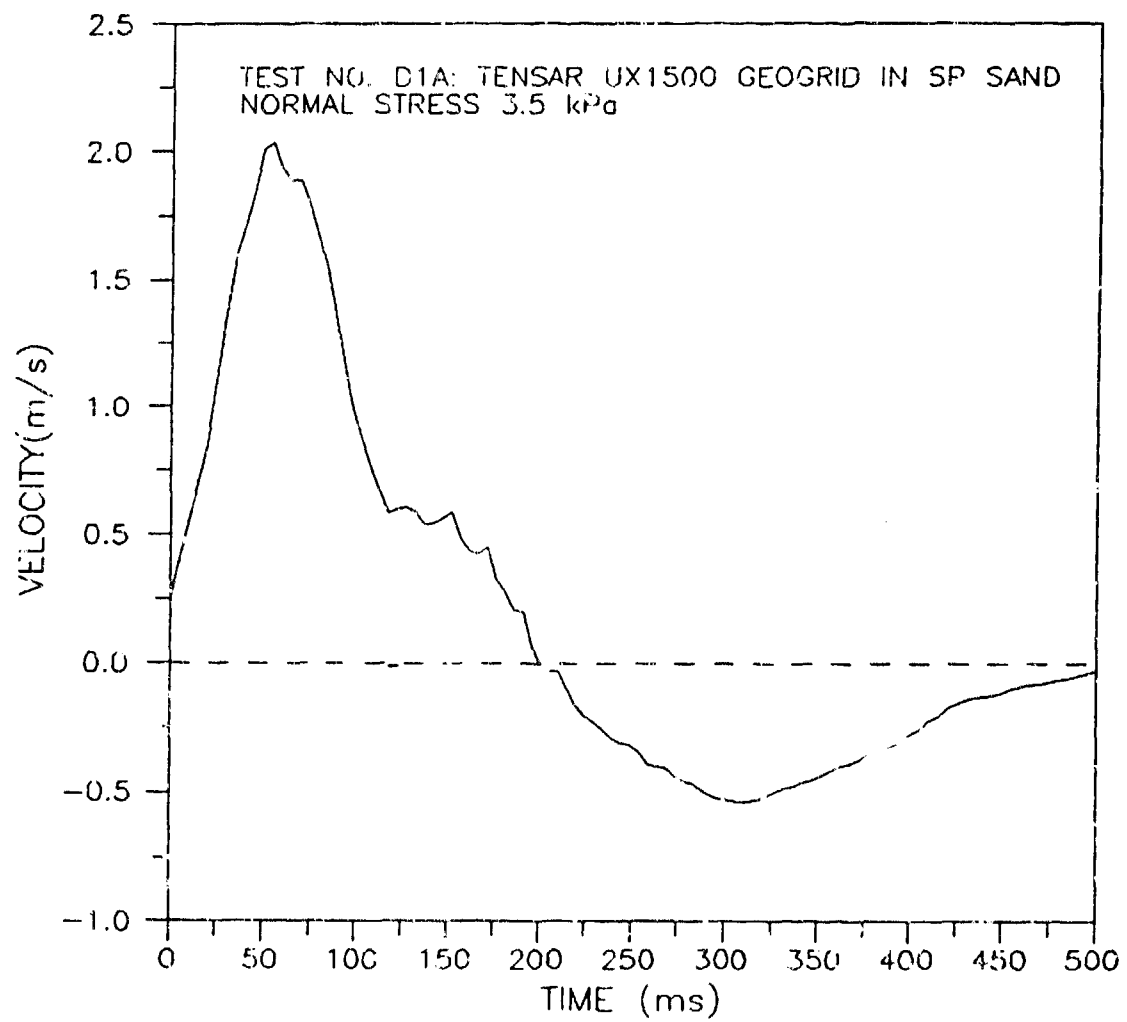
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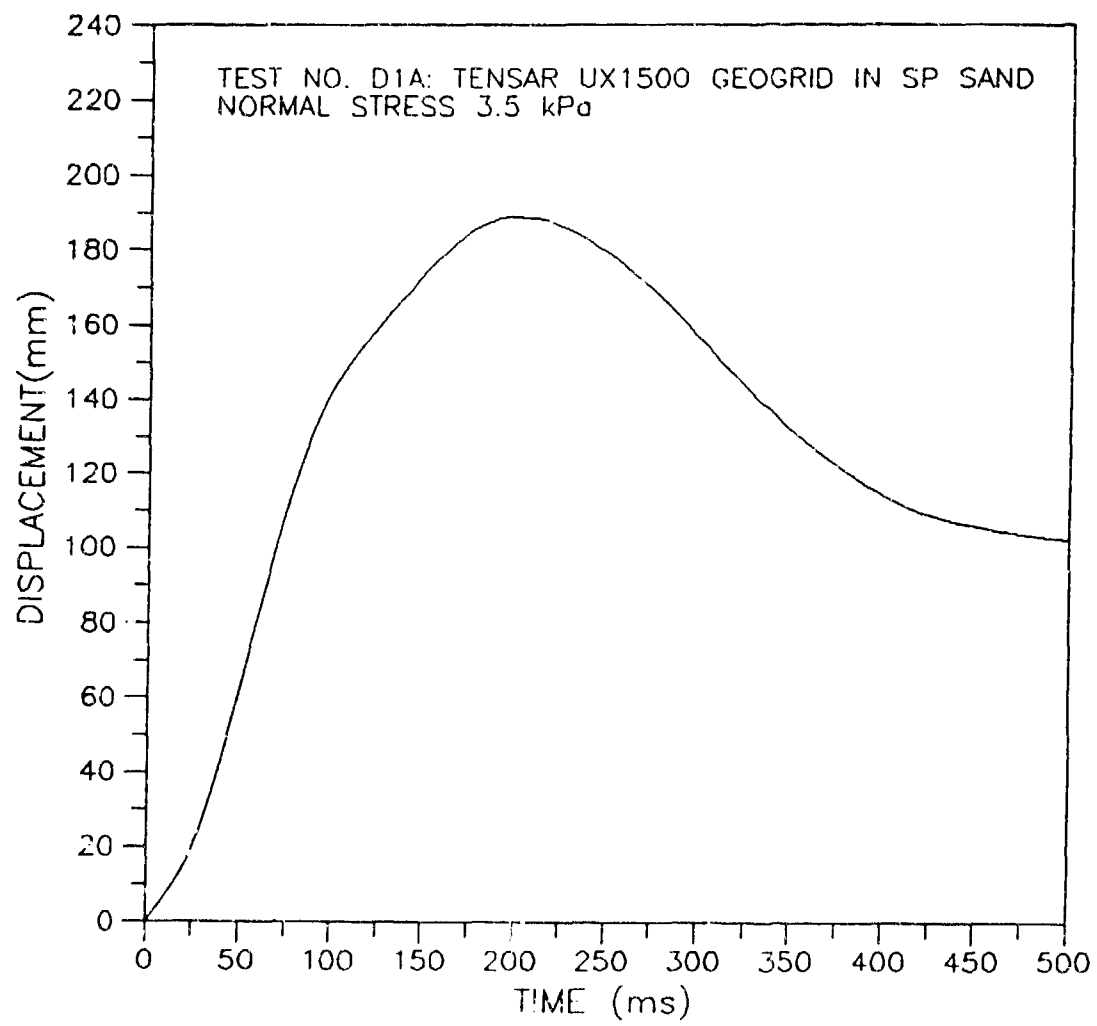
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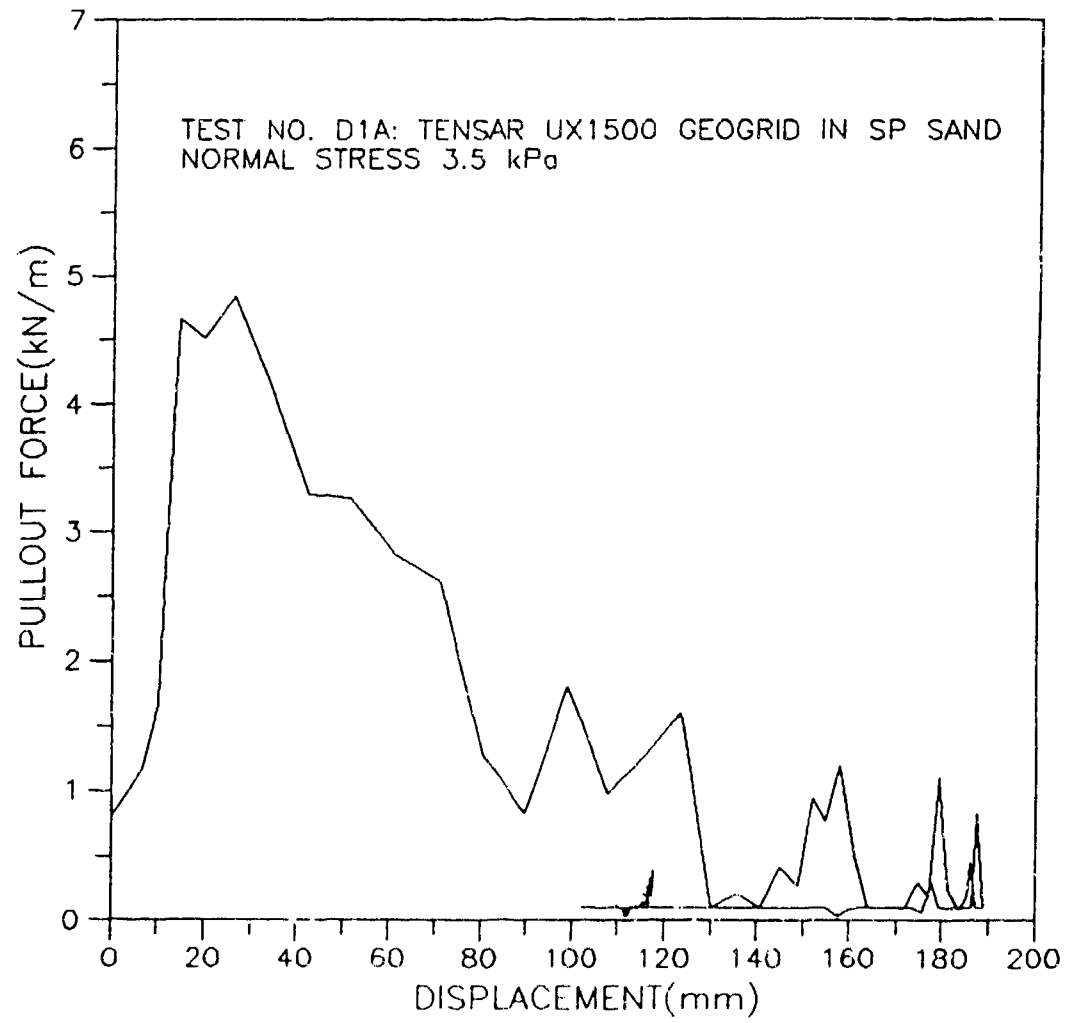
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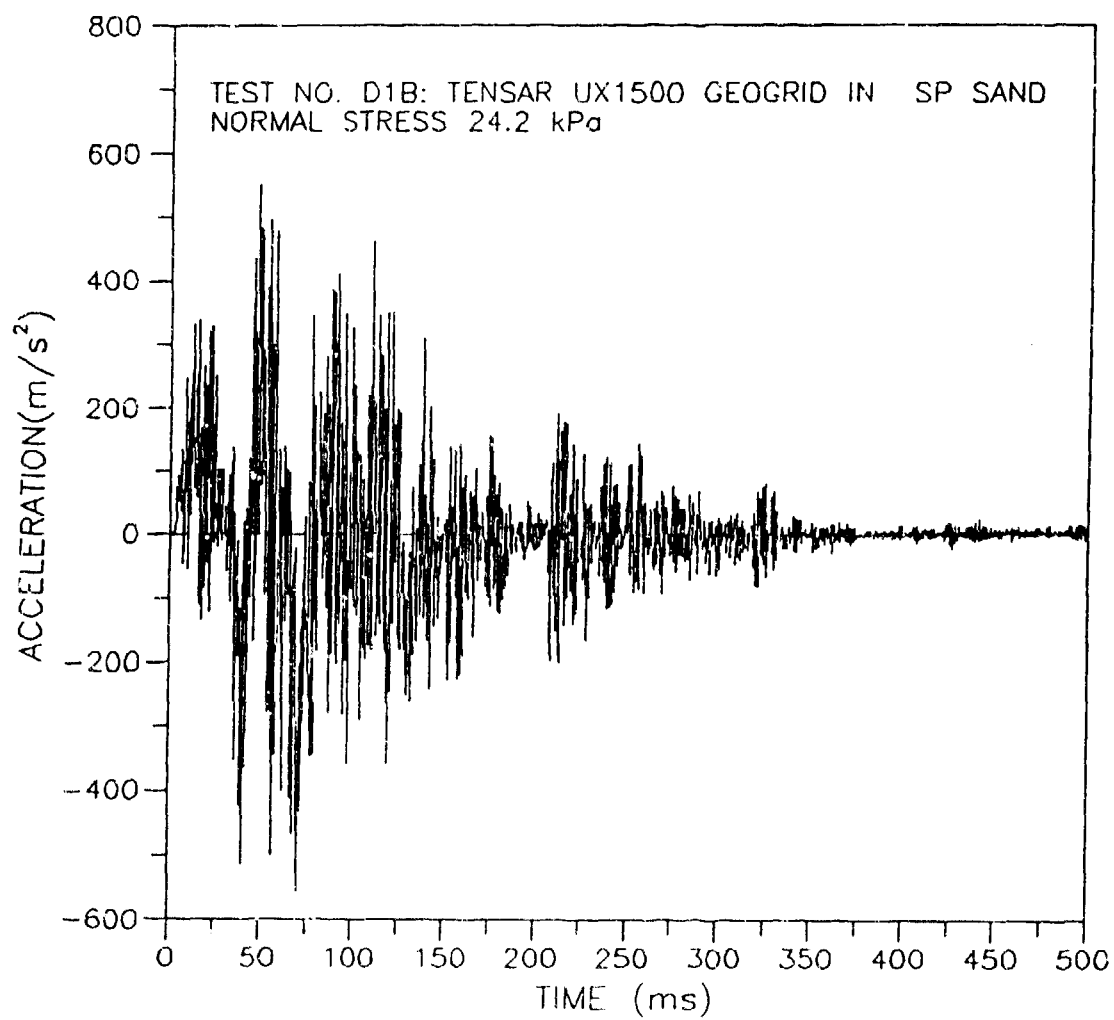
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Geogrid for Test D1B.

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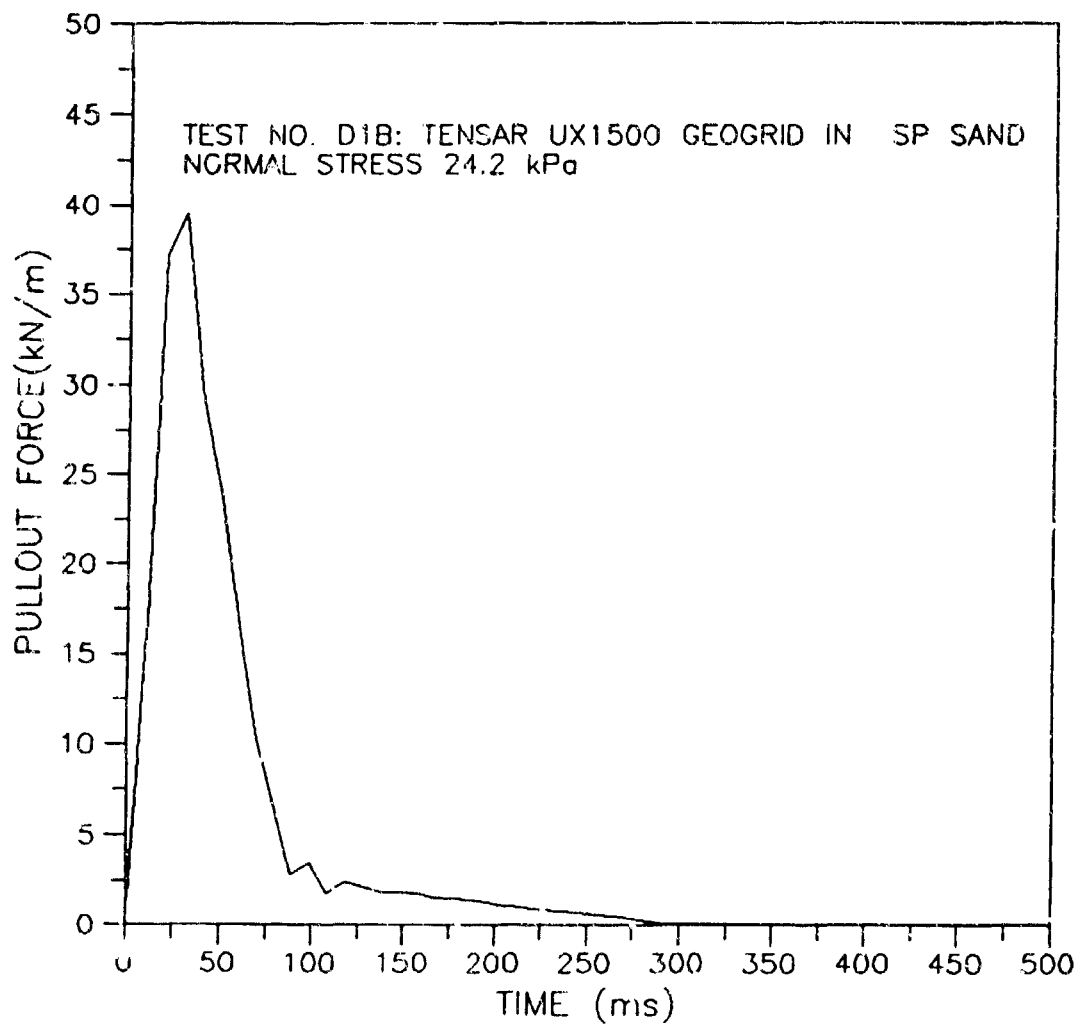
Figure 31. Measured Force at Pulling End of Tensar UX1500 Geogrid for Test D1B.

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TEST NO. D1B: TENSAR UX1500 GEOGRID IN SP SAND
NORMAL STRESS 24.2 kPa
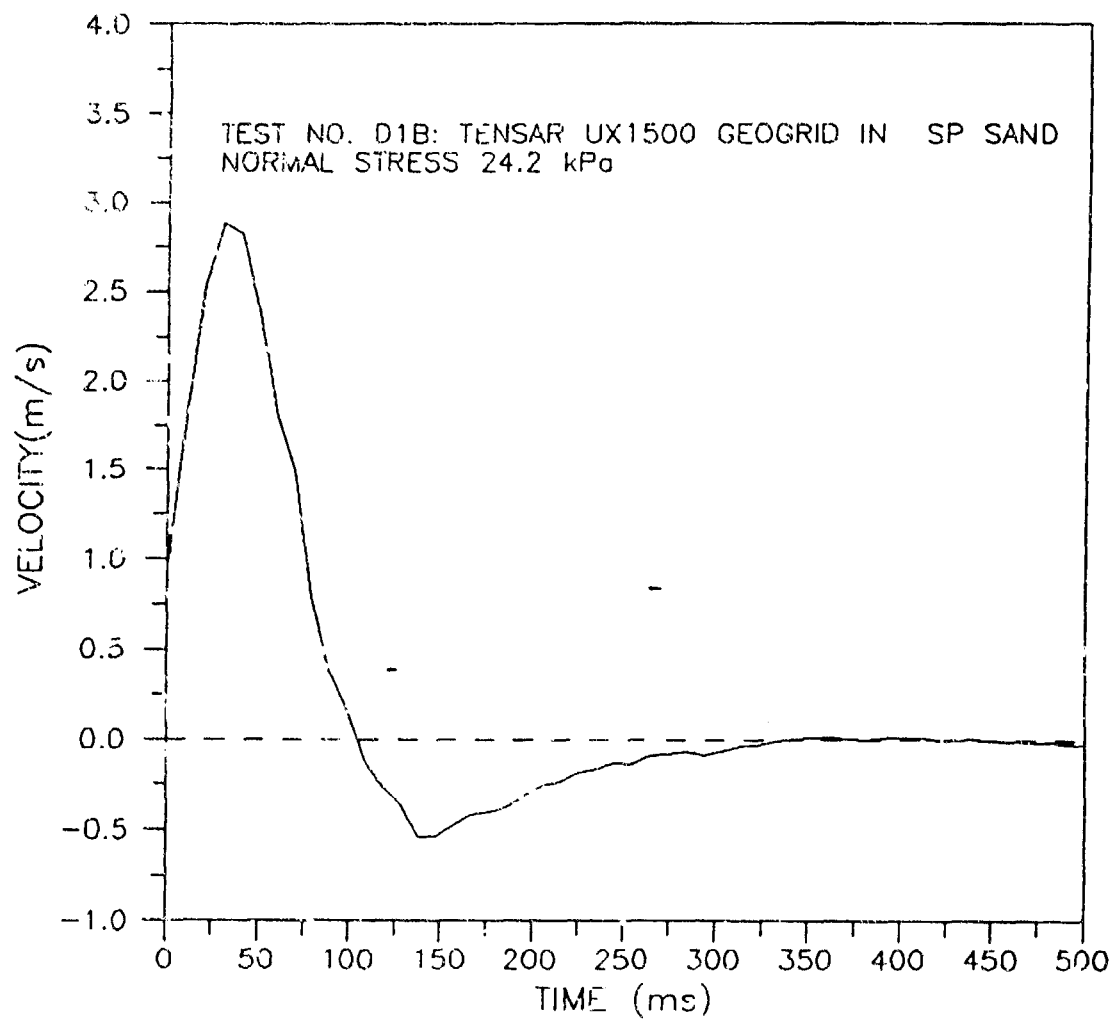
Figure 32. Velocity Time History at Pulling End of Tensar UX1500
Geogrid for Test D1B.

37

TEST NO. D1B: TENSAR UX1500 GEOGRID IN SP SAND NORMAL STRESS 24.2 kPa
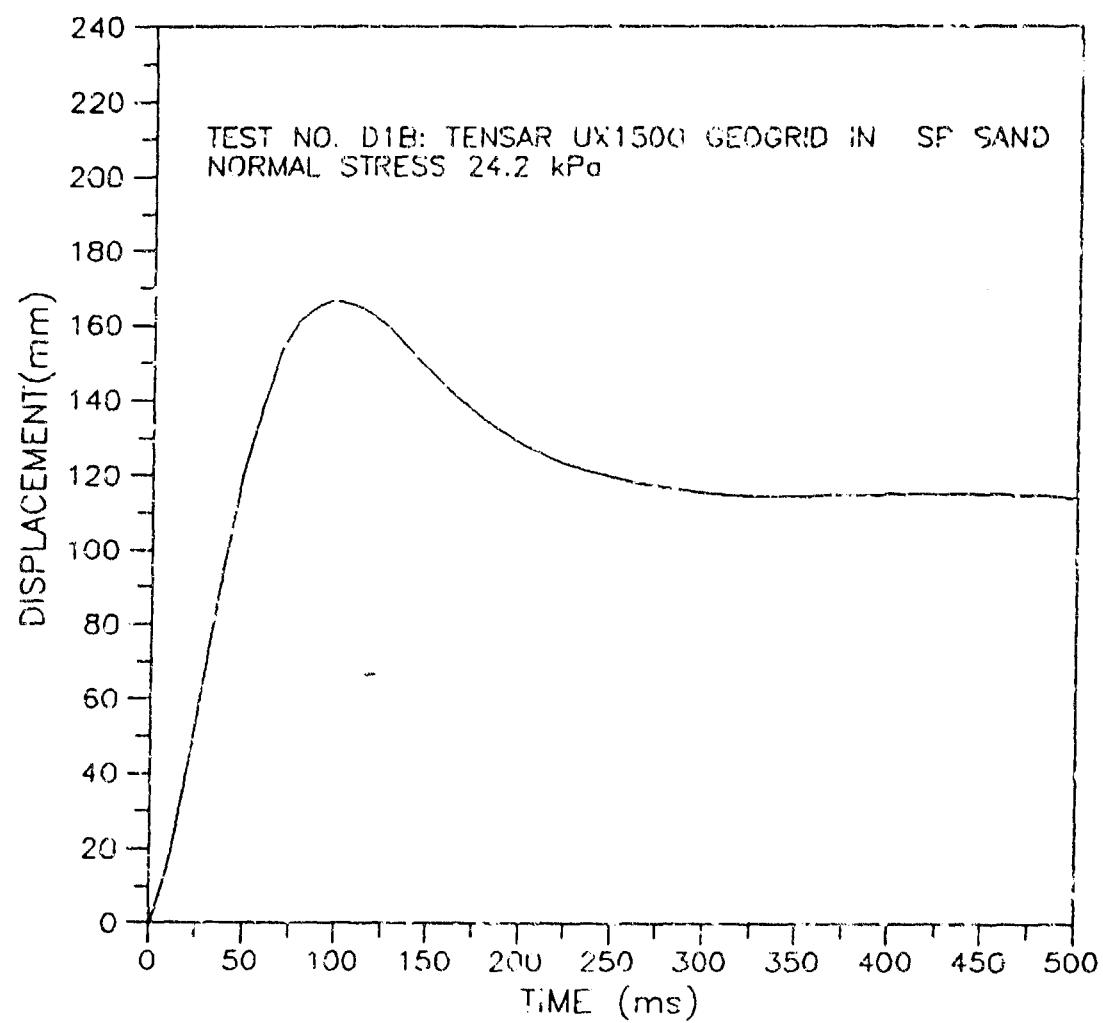
Figure 33. Displacement Time History at Pulling End of Tensar UX1500 Geogrid for Test D1B.

38
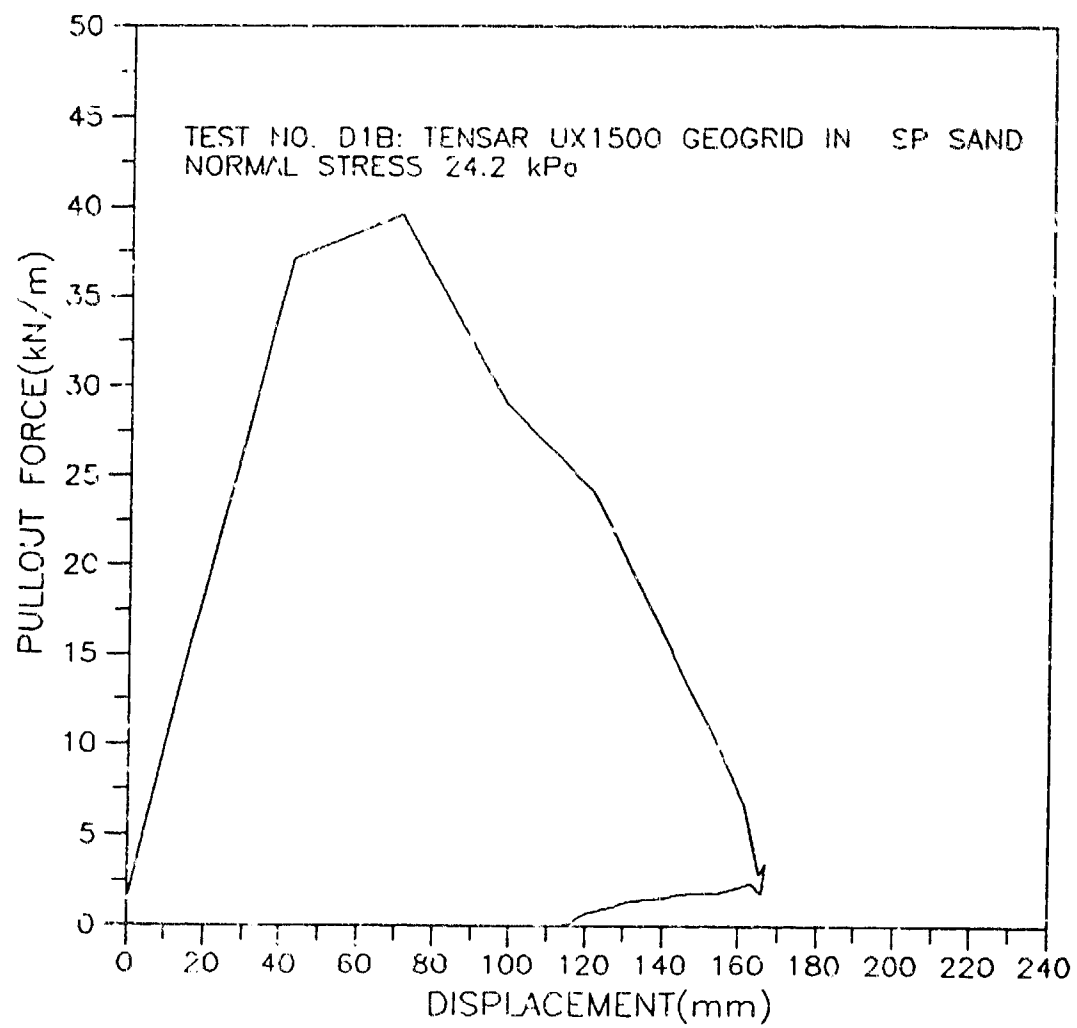
Figure 34. Dynamic Pullout Response of Tensar UX1500 Geogrid
for Test D1B.

39
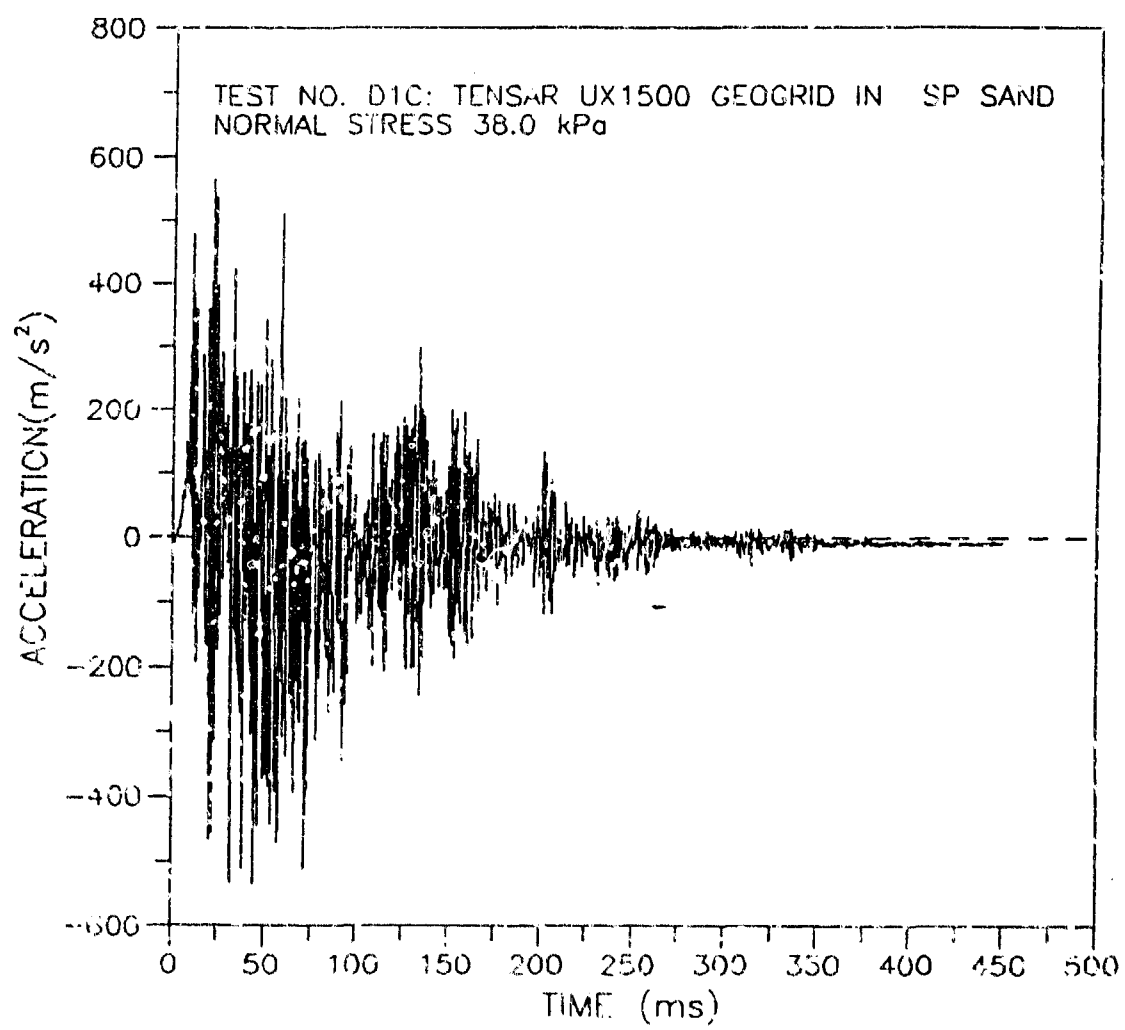
Figure 35. Measured Acceleration at Pulling End of Tensar UX1500
Geogrid for Test DIC.

40
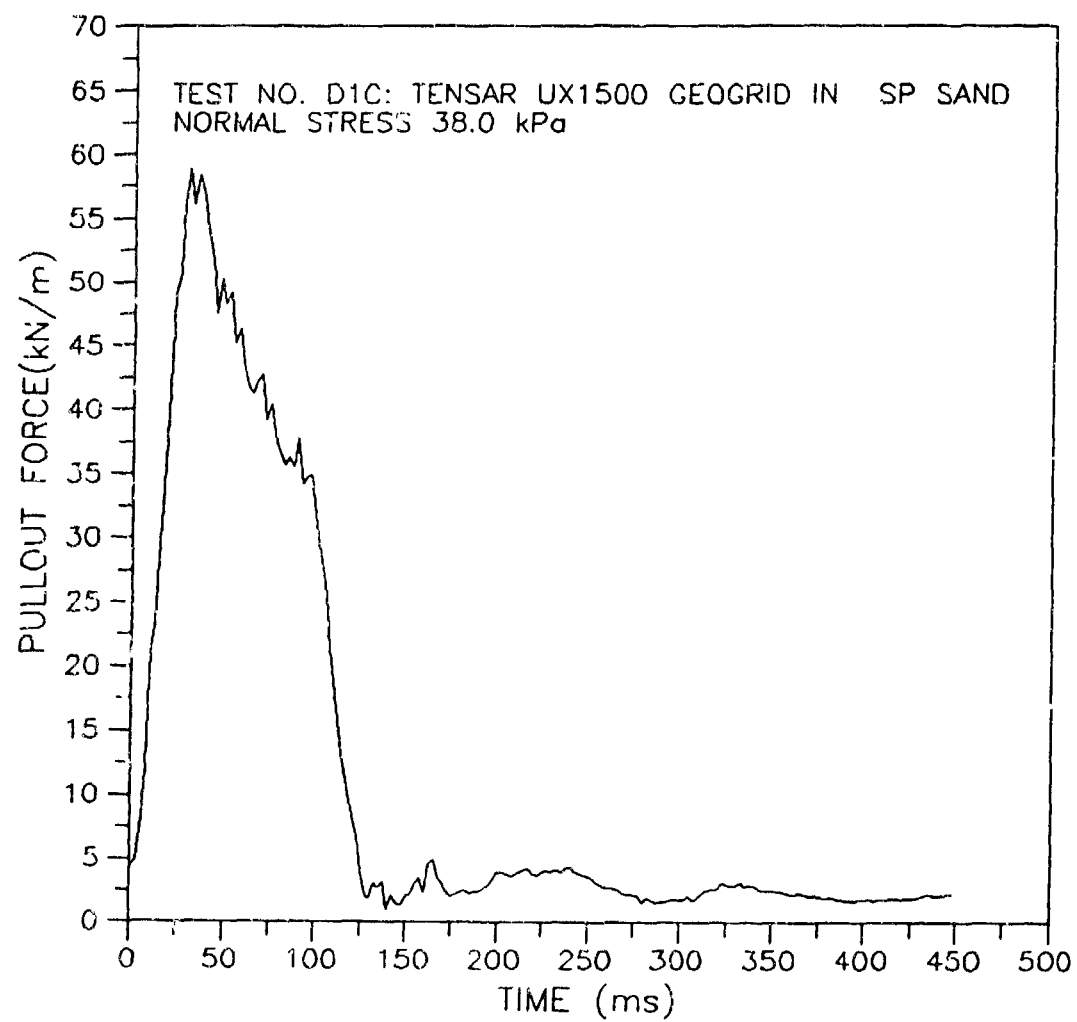
Figure 36. Measured Force at Pulling End of Tensar UX1500 Geogrid
for Test D1C.

41

TEST NO. D1C: TENSAR UX1500 GEOGRID IN SP SAND
NORMAL STRESS 38.0 kPa
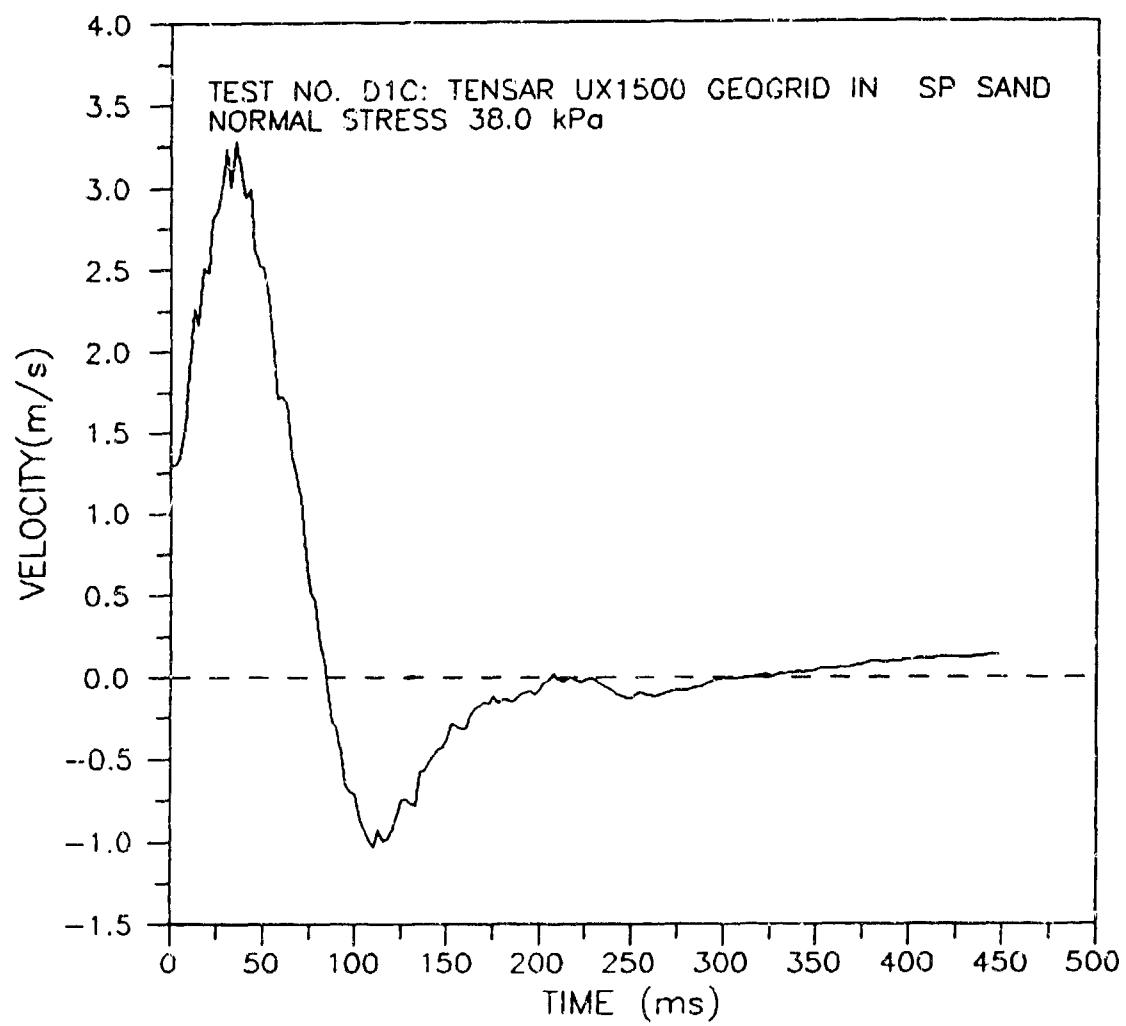
Figure 37. Velocity Time History at Pulling End of Tensar UX1500
Geogrid for Test D1C.

42
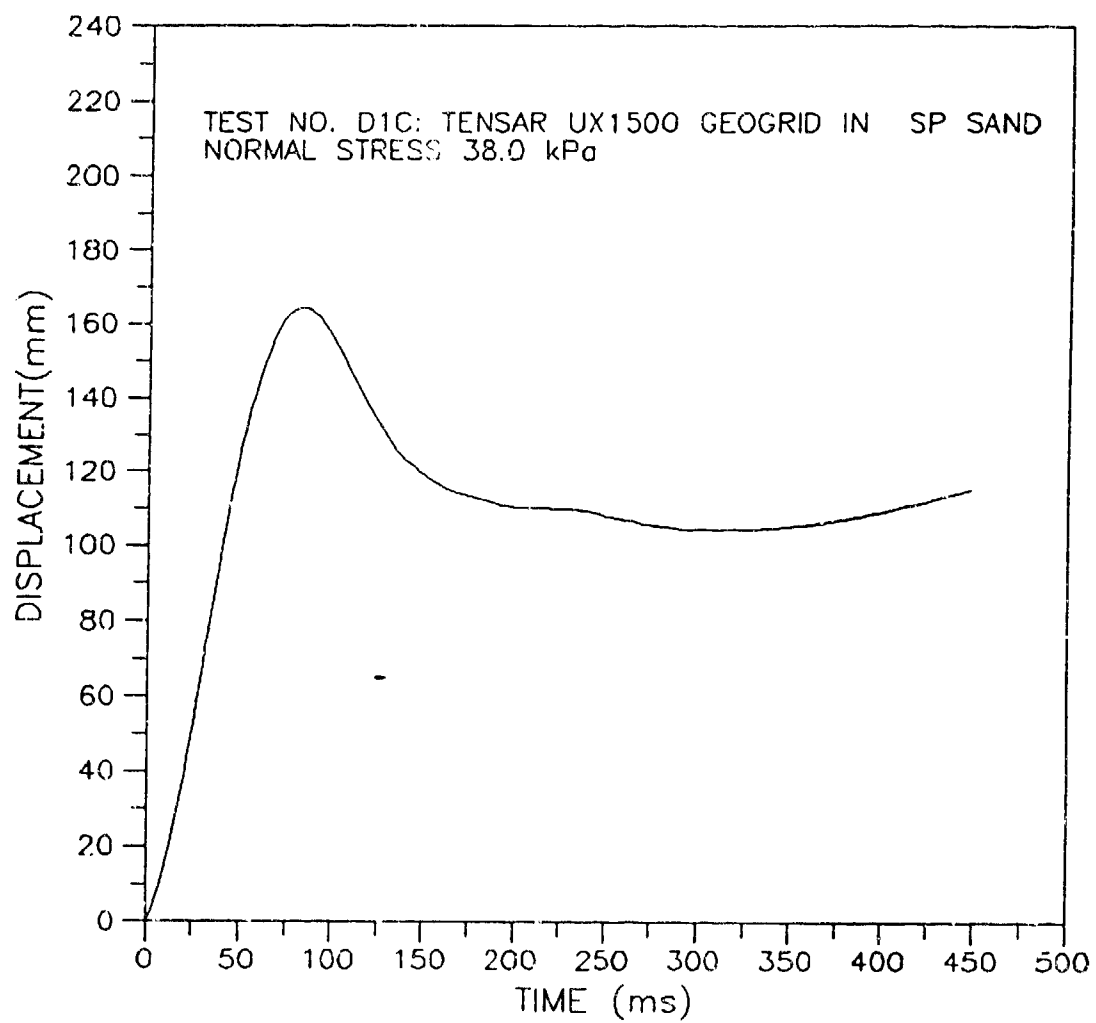
Figure 38. Displacement Time History at Pulling End of Tensar UX1500 Geogrid for Test D1C.

43
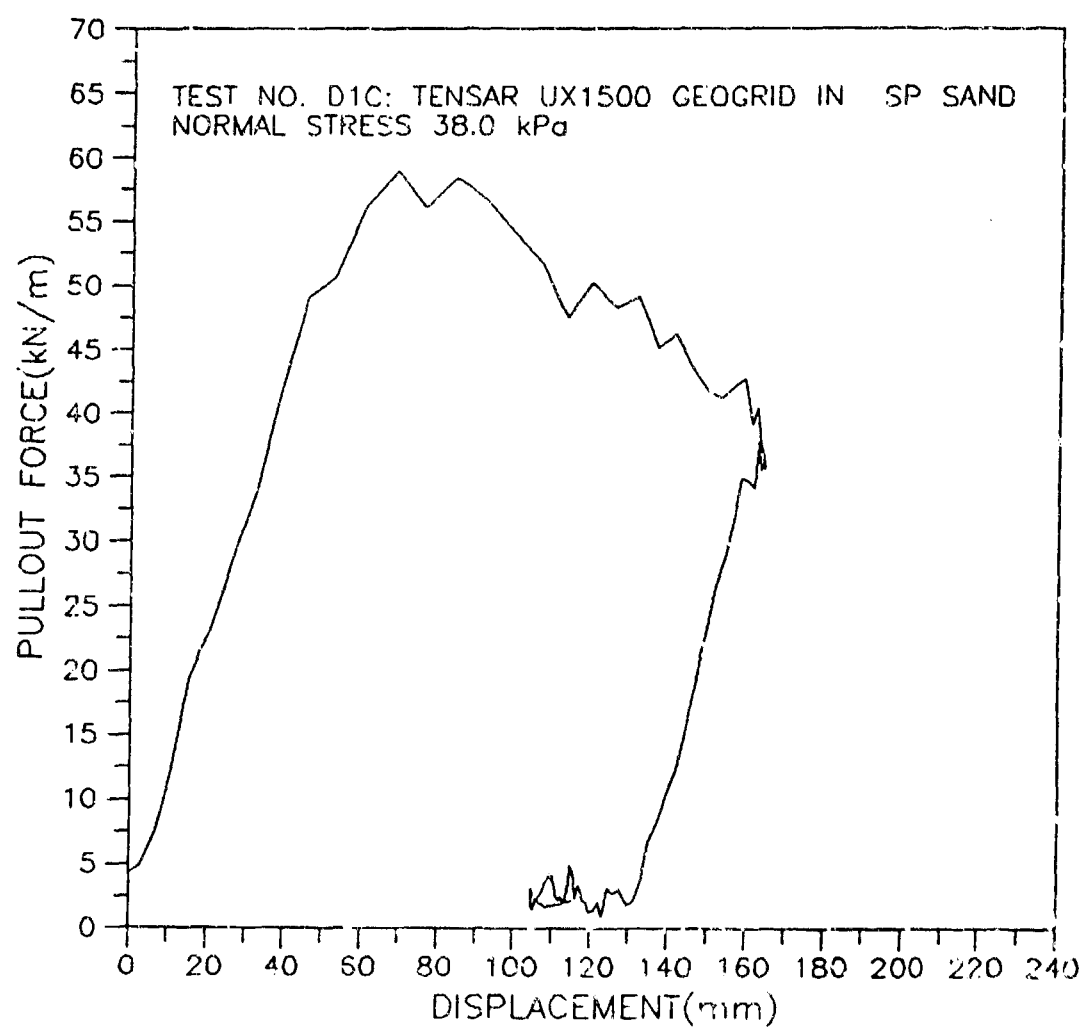
Figure 39. Dynamic Pullout Response of Tensar UX1500 Geogrid
for Test D1C.

44
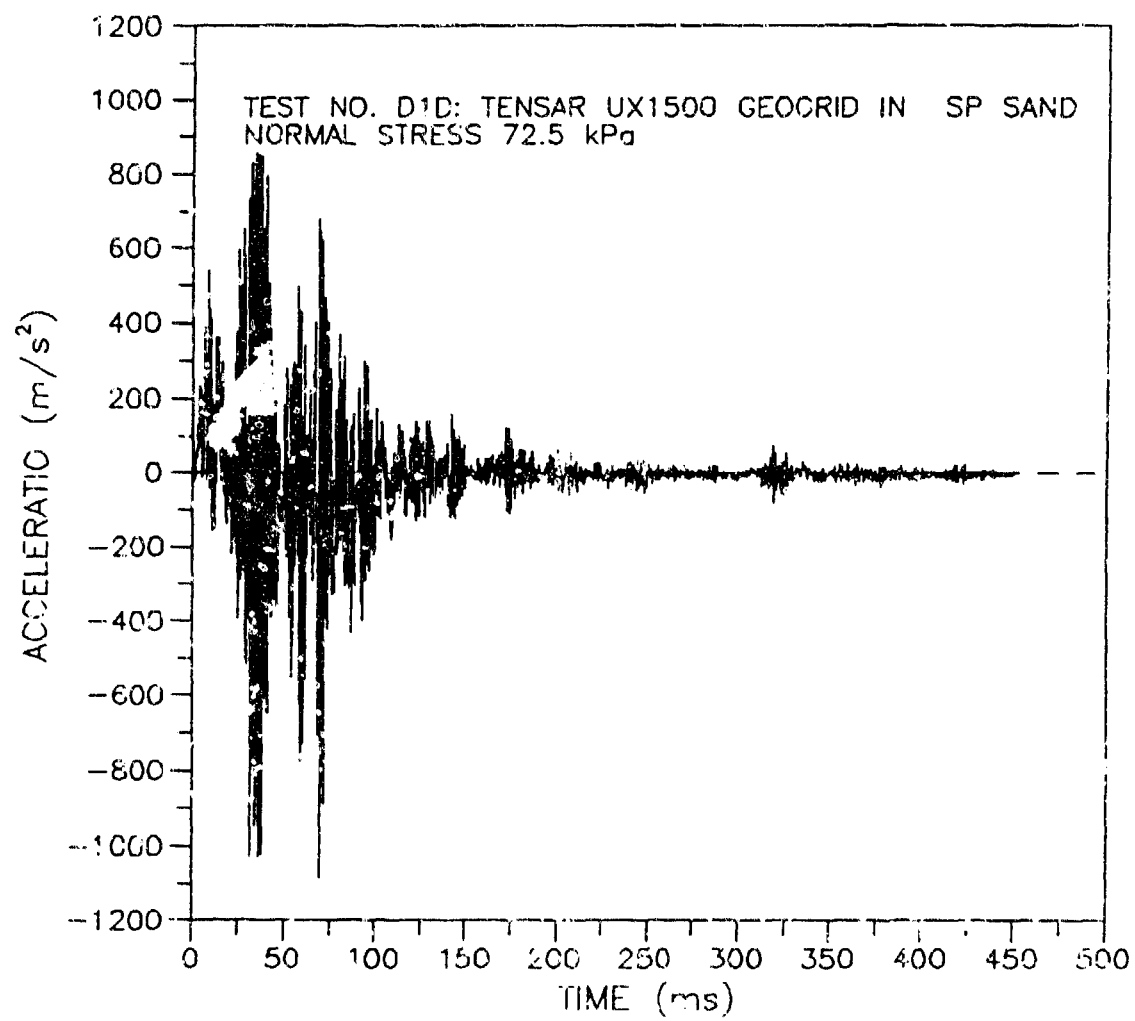
Figure 40. Measured Acceleration at Pulling End of Tensar UX1500 Geogrid for Test D1D.

45

TEST NO. D1D: TENSAR UX1500 GEOGRID IN   SP SAND
NORMAL STRESS 72.5 kPa
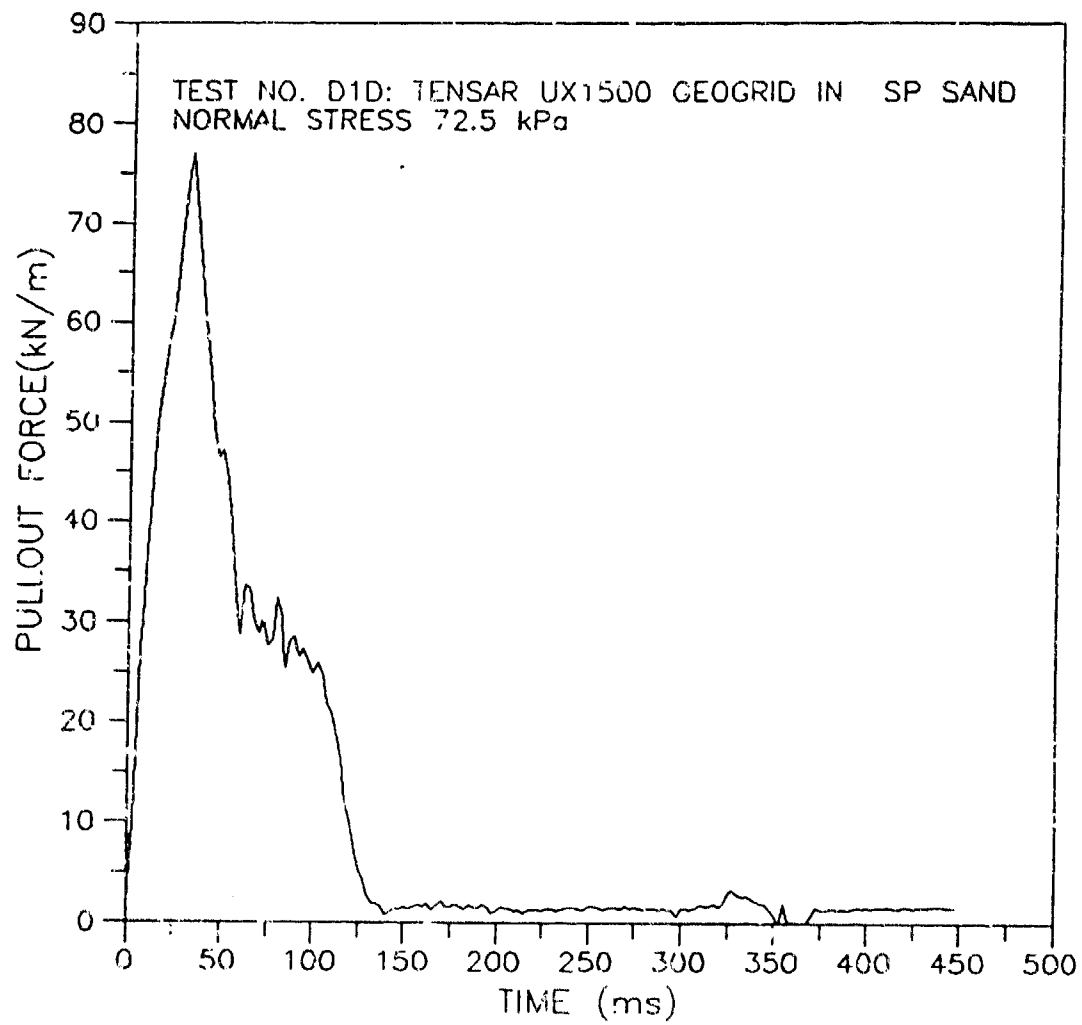
Figure 41.   Measured Force at Pulling End of Tensar UX1500 Geogrid
for Test D1D.

46
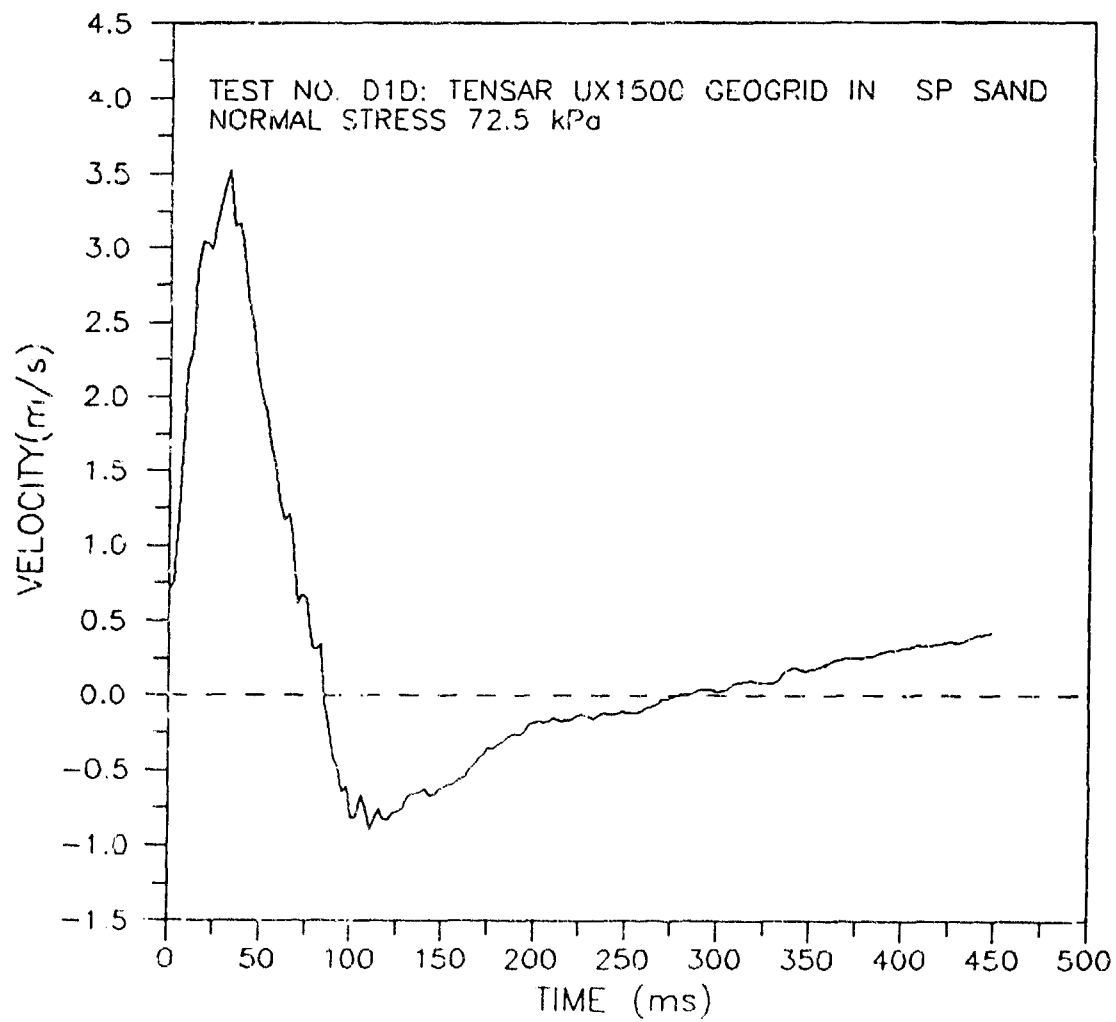
Figure 42.   Velocity Time History at Pulling End of Tensar UX1500
             Geogrid for Test D1D.

47

TEST NO. D1D: TENSAR UX1500 GEOGRID IN SP SAND
NORMAL STRESS 72.5 kPa
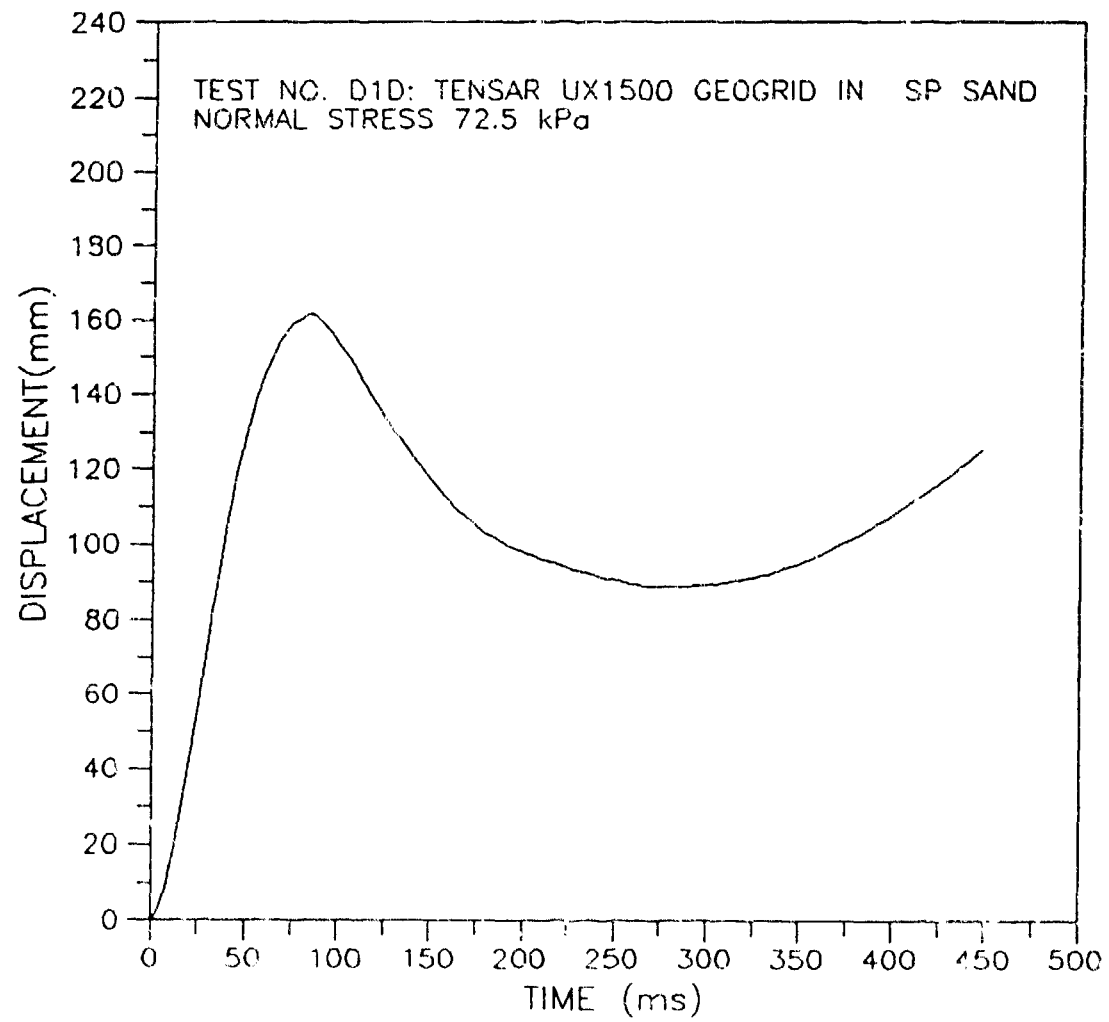
Figure 43. Displacement Time History at Pulling End of Tensar UX1500
Geogrid for Test D1D.

48
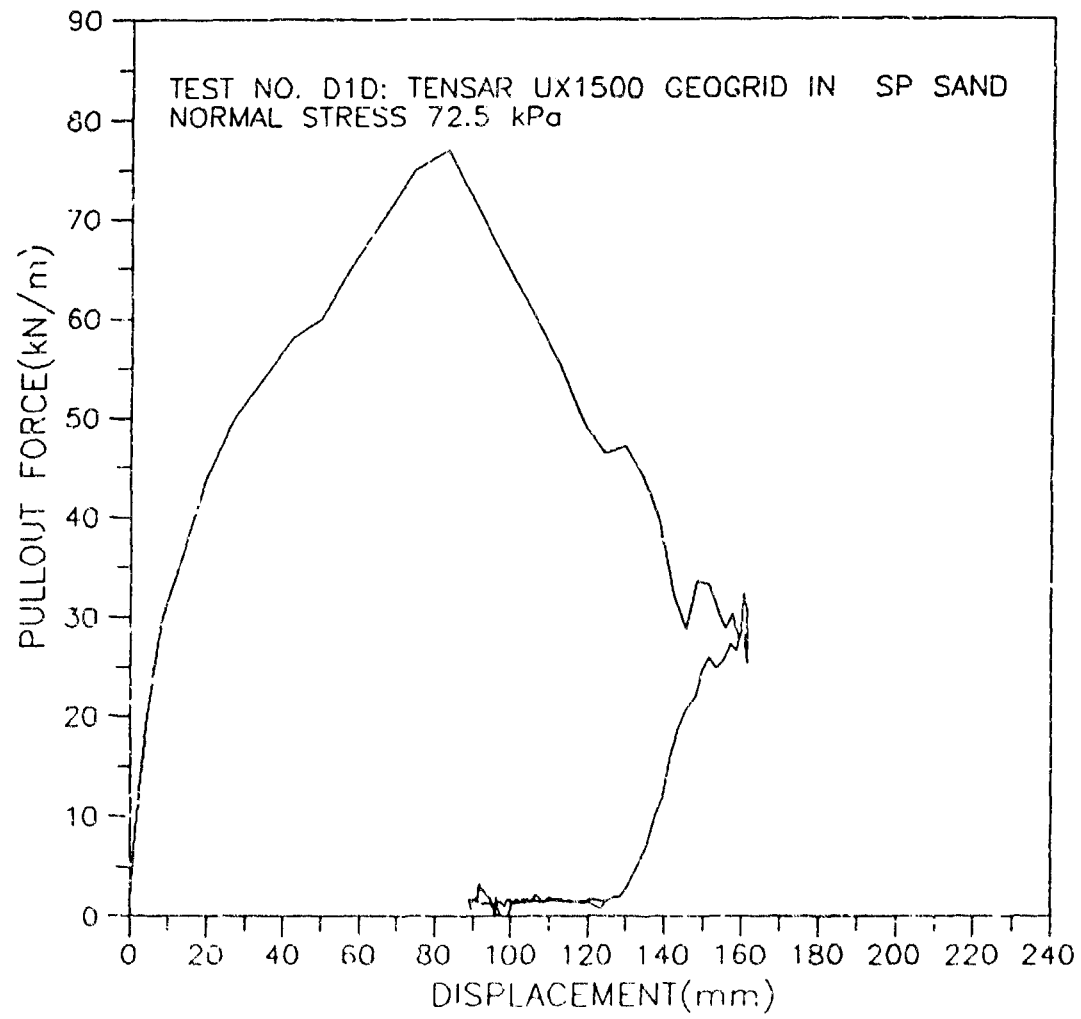
Figure 44. Dynamic Pullout Response of Tensar UX1500 Geogrid for Test D1D.

49
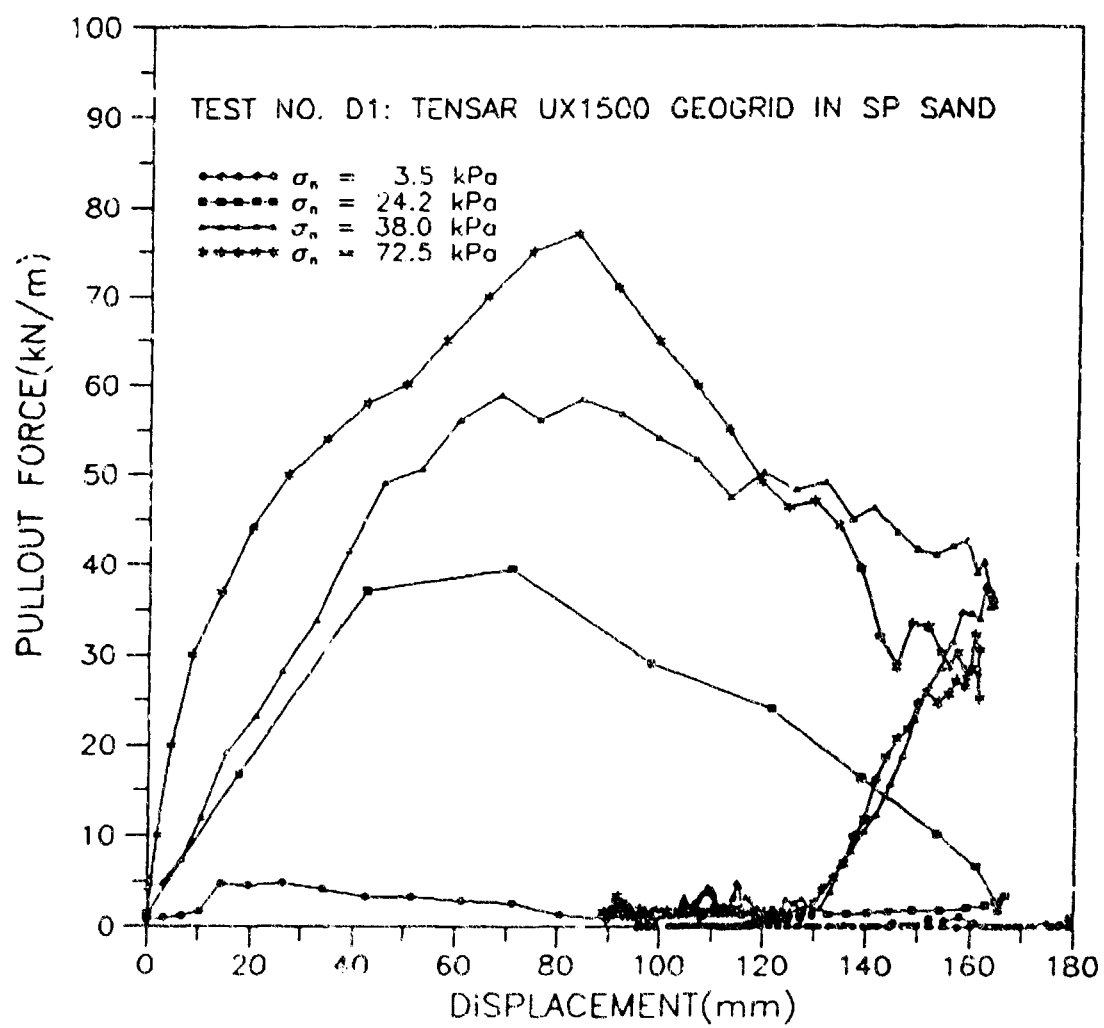
Figure 45. Dynamic Pullout Responses of Tensar UX1500 Geogrid
for Test D1A, D1B, D1C, and D1D.

50
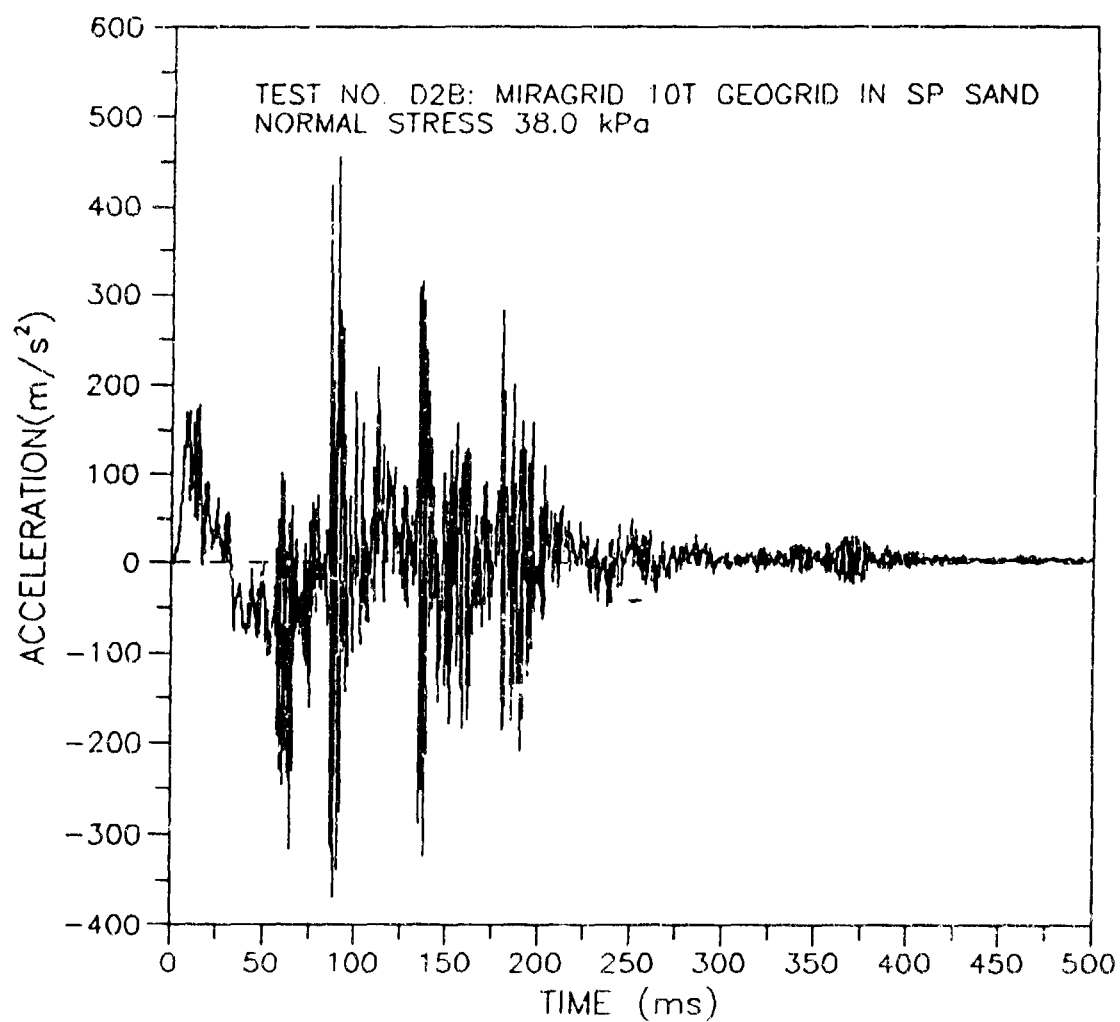
Figure 46. Measured Acceleration at Pulling End of Miragrid 10T Geogrid for Test D2B.

51
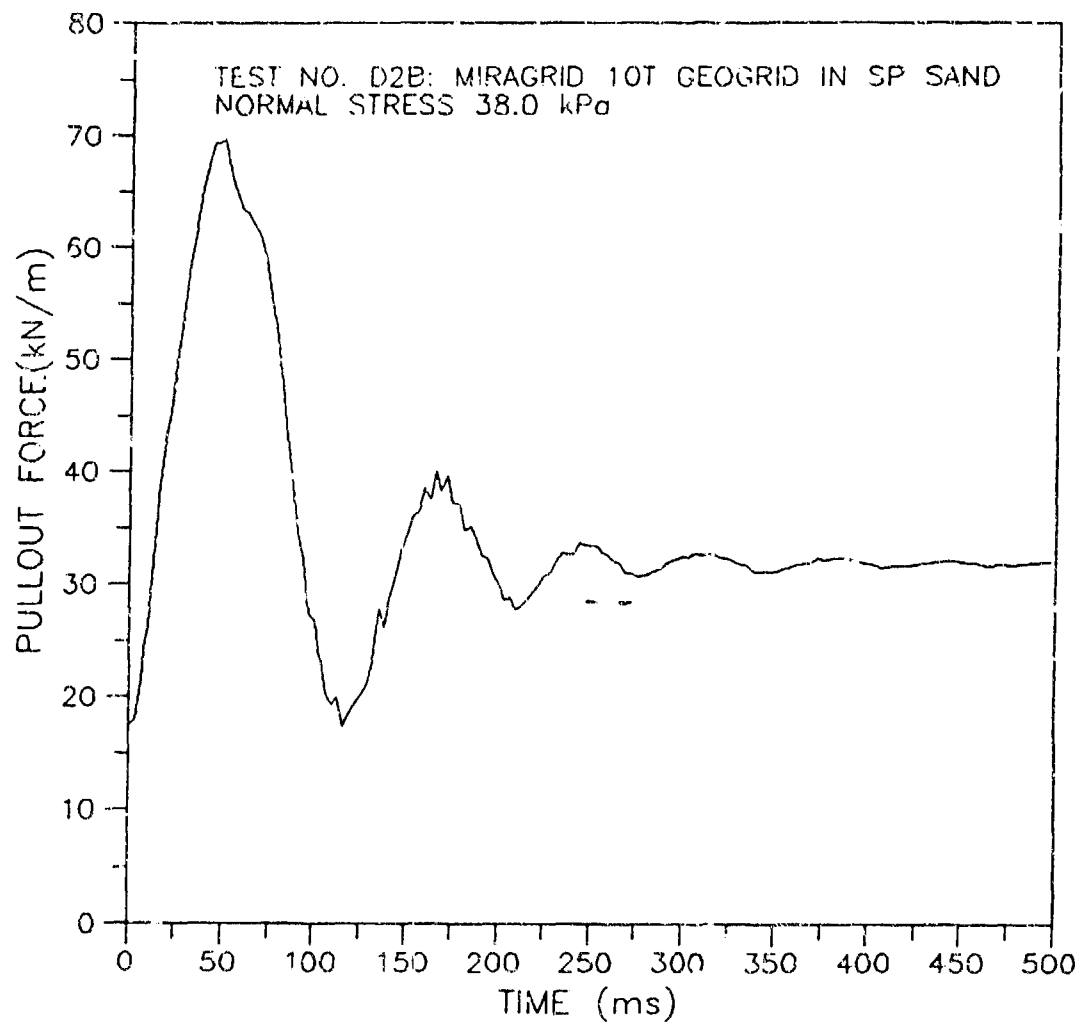
Figure 47. Measured Force at Pulling End of Miragrid 10T Geogrid
            for Test D2B.

52
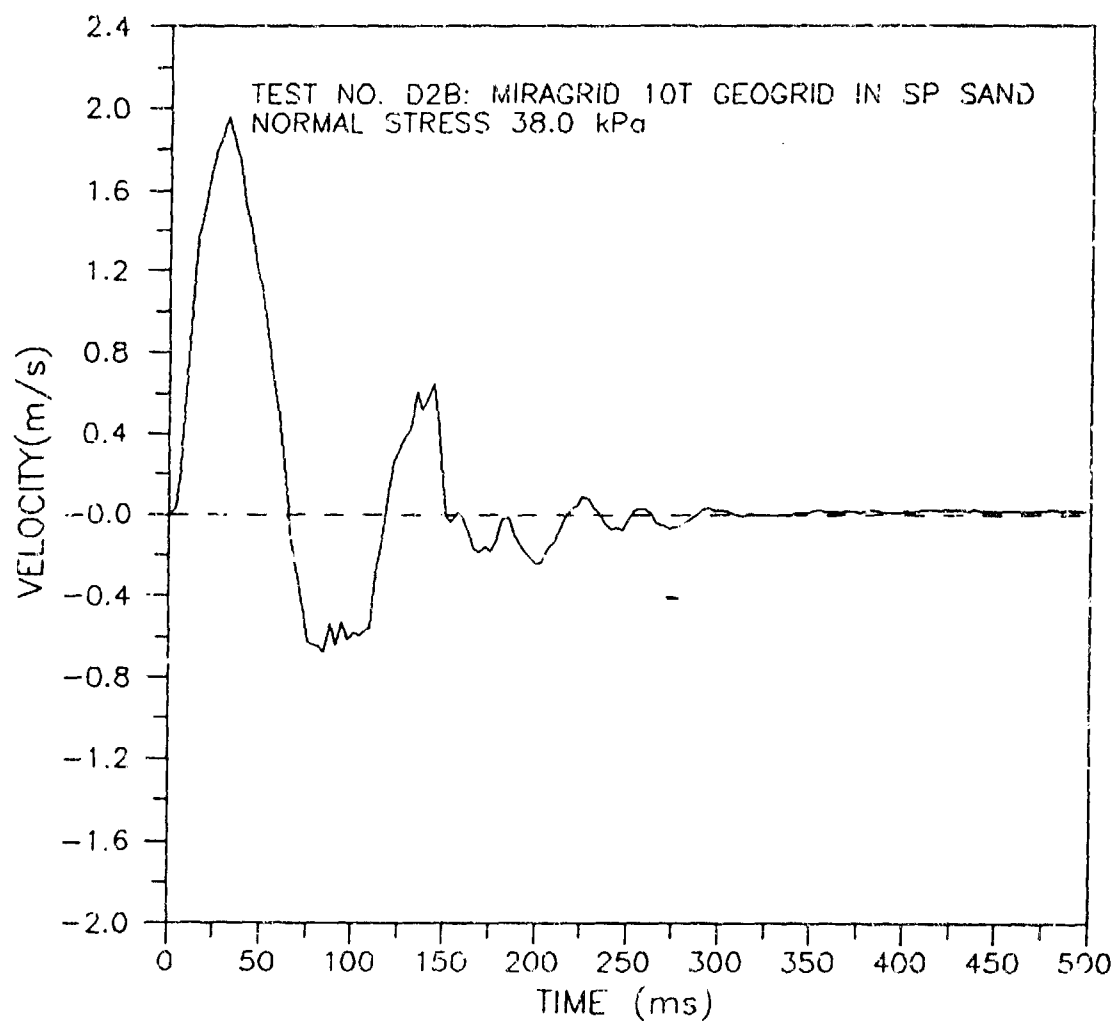
Figure 48. Velocity Time History at Pulling End of Miragrid 10T Geogrid for Test D2B.
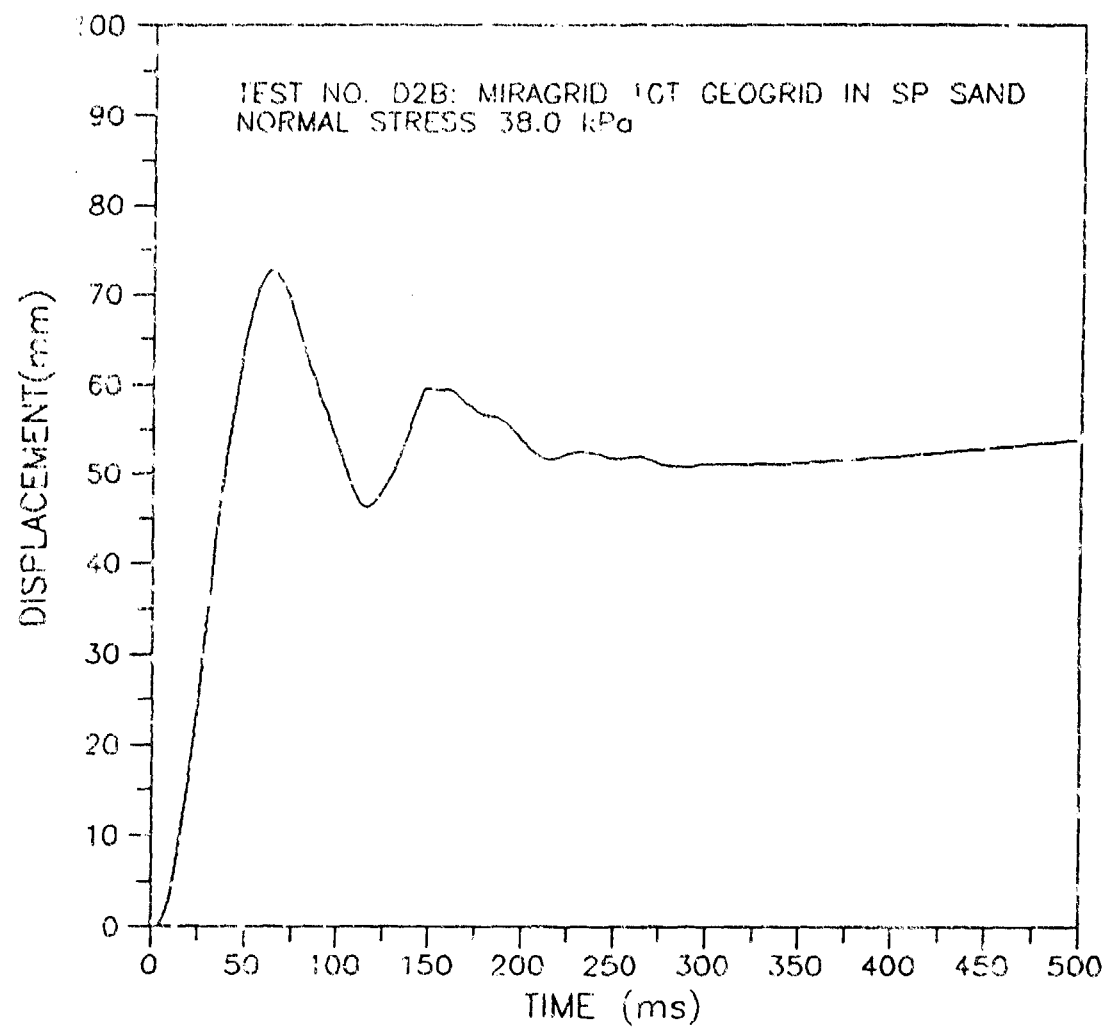
Figure 49. Displacement Time History at Pulling End of Miragrid 10T
            Geogrid for Test D2B.

54
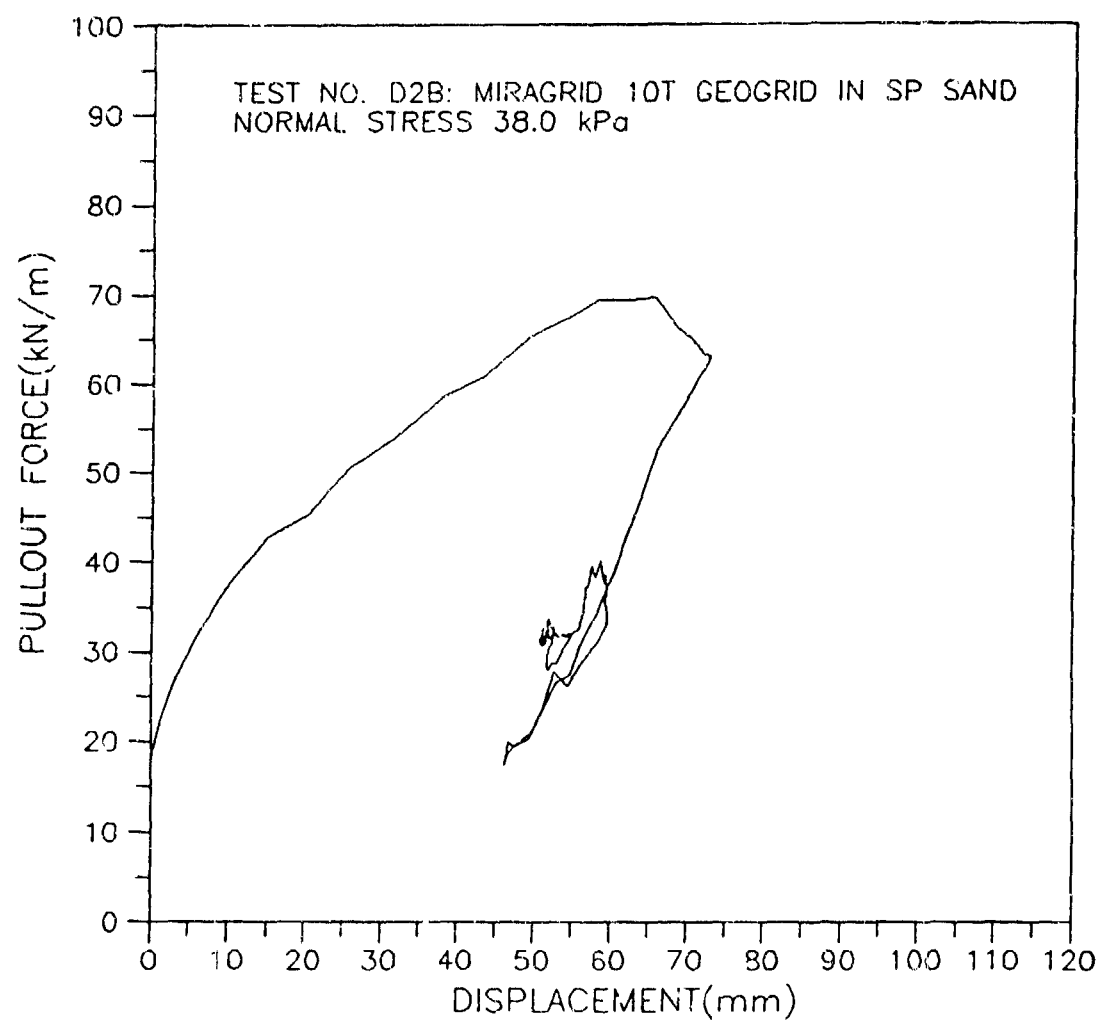
Figure 50. Dynamic Pullout Response of Miragrid 10T Geogrid for Test D2B.

55

TEST NO. D2C: MIRAGRID 10T GEOGRID IN SP SAND
NORMAL STRESS 72.5 kPa
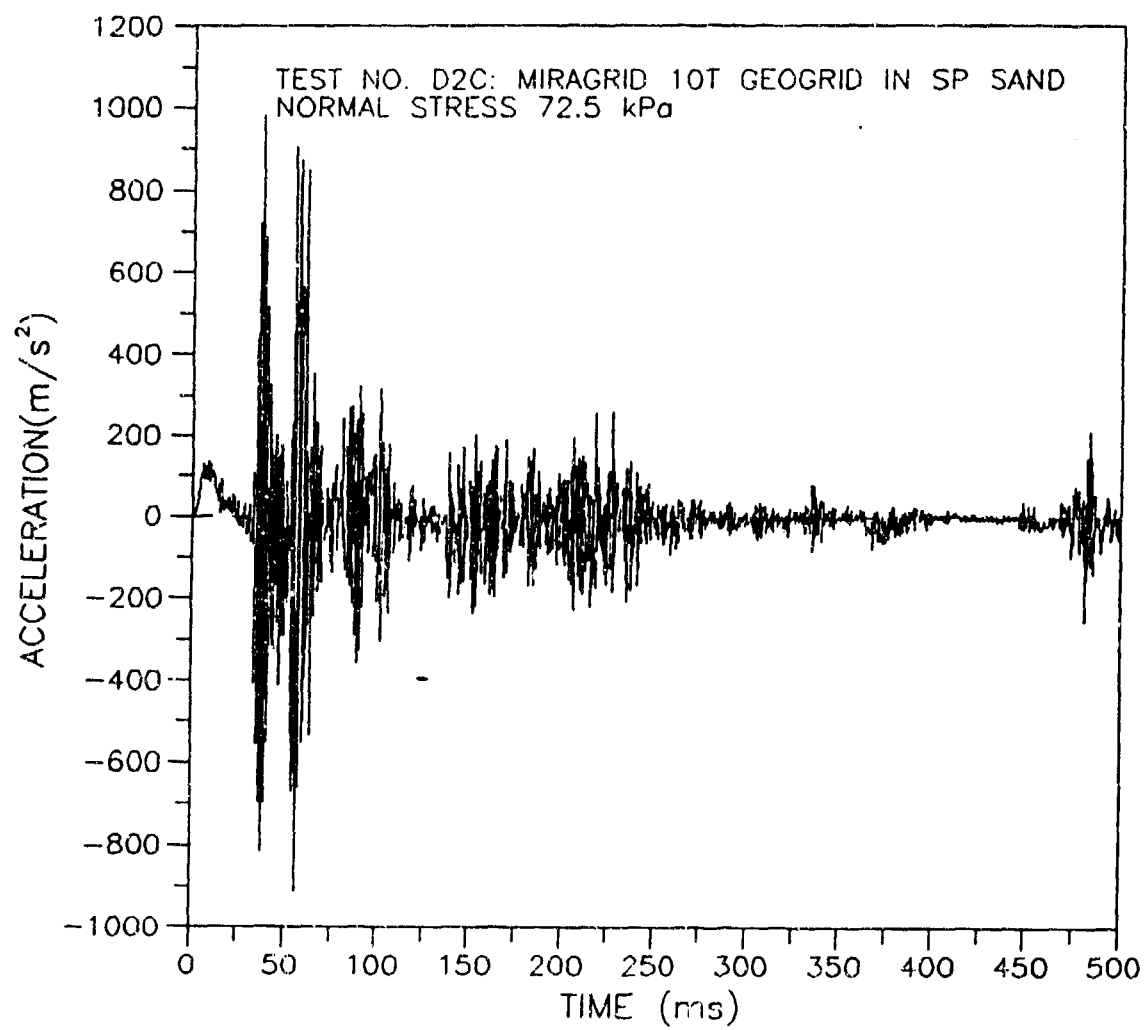
Figure 51.   Measured Acceleration at Pulling End of Miragrid 10T
            Geogrid for Test D2C.

56
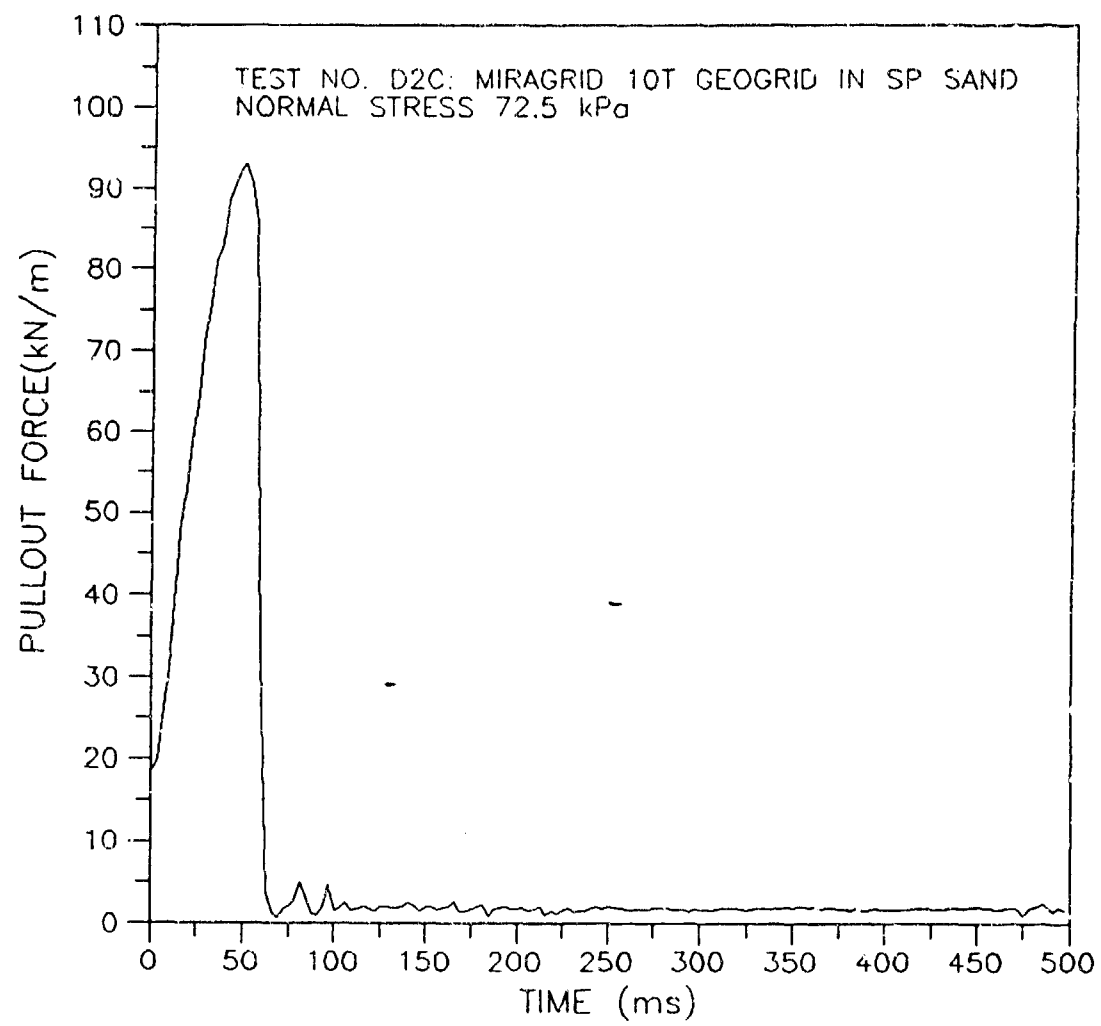
Figure 52.   Measured Force at Pulling End of Miragrid 10T Geogrid
            for Test D2C.

57
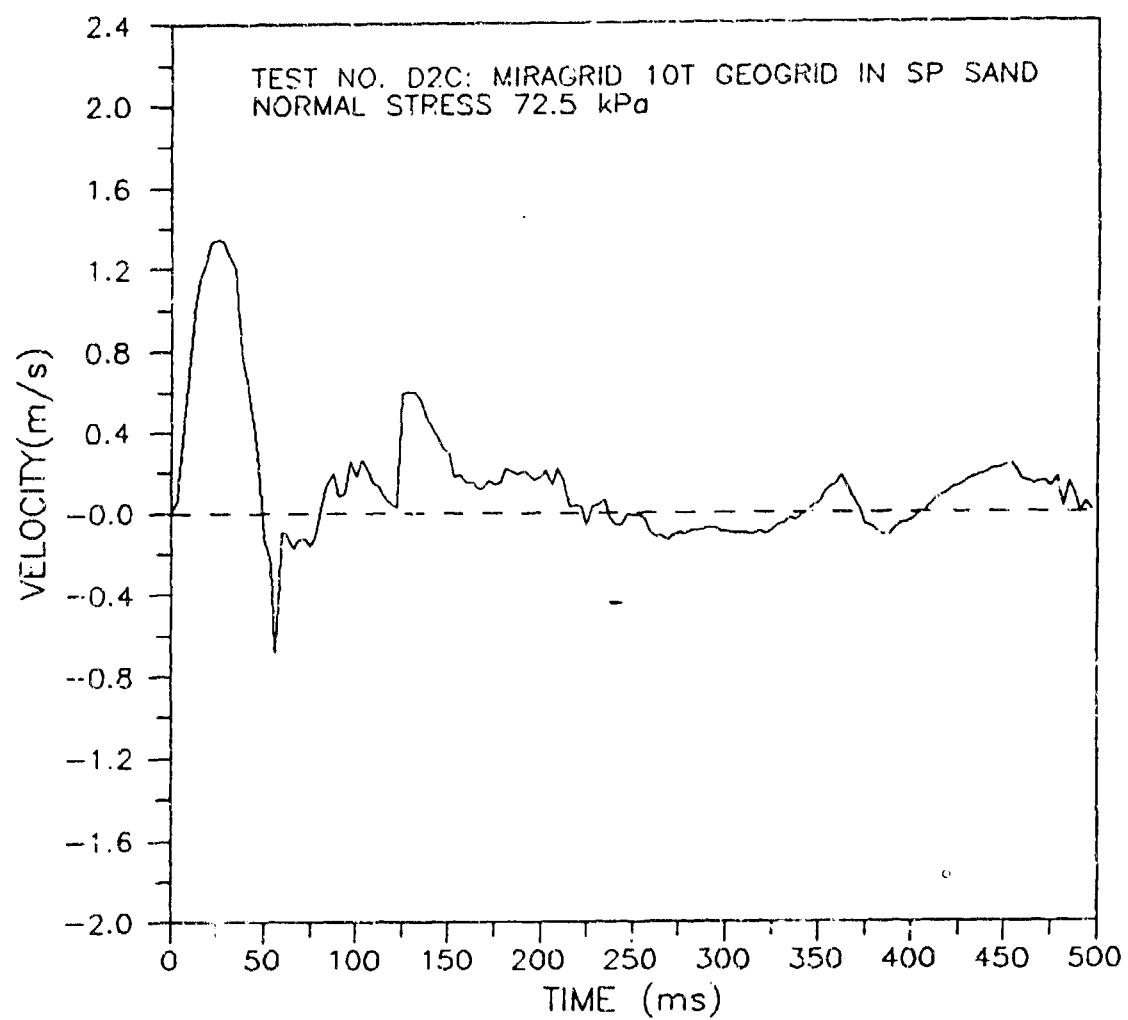
Figure 53. Velocity Time History at Pulling End of Miragrid 10T Geogrid for Test D2C.

58

TEST NO. D2C: MIRAGRID 10T GEOGRID IN SP SAND
NORMAL STRESS 72.5 kPa
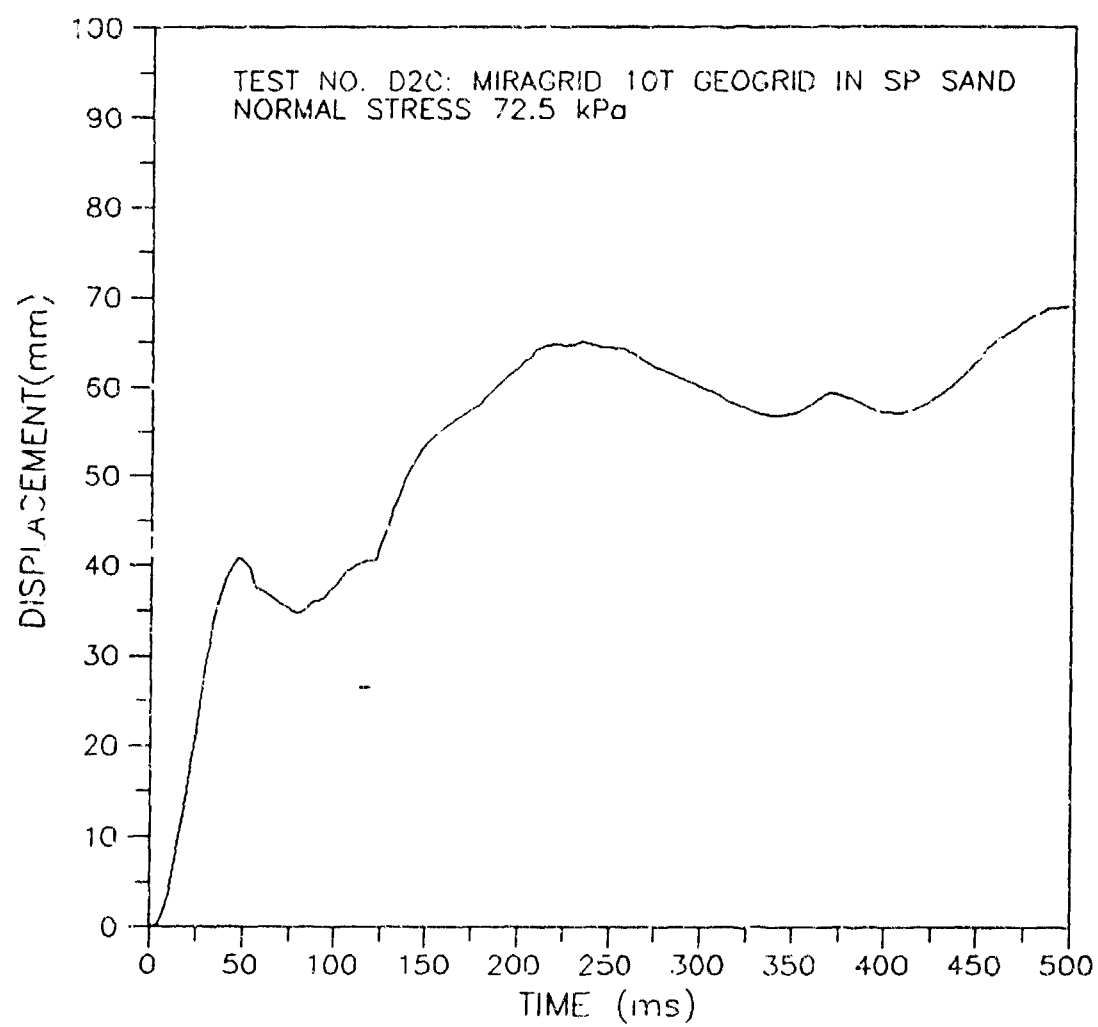
Figure 54.   Displacement Time History at Pulling End of Miragrid 10T
             Geogrid for Test D2C.

59

TEST NO. D2C: MIRAGRID 10T GEOGRID IN SP SAND
NORMAL STRESS 72.5 kPa
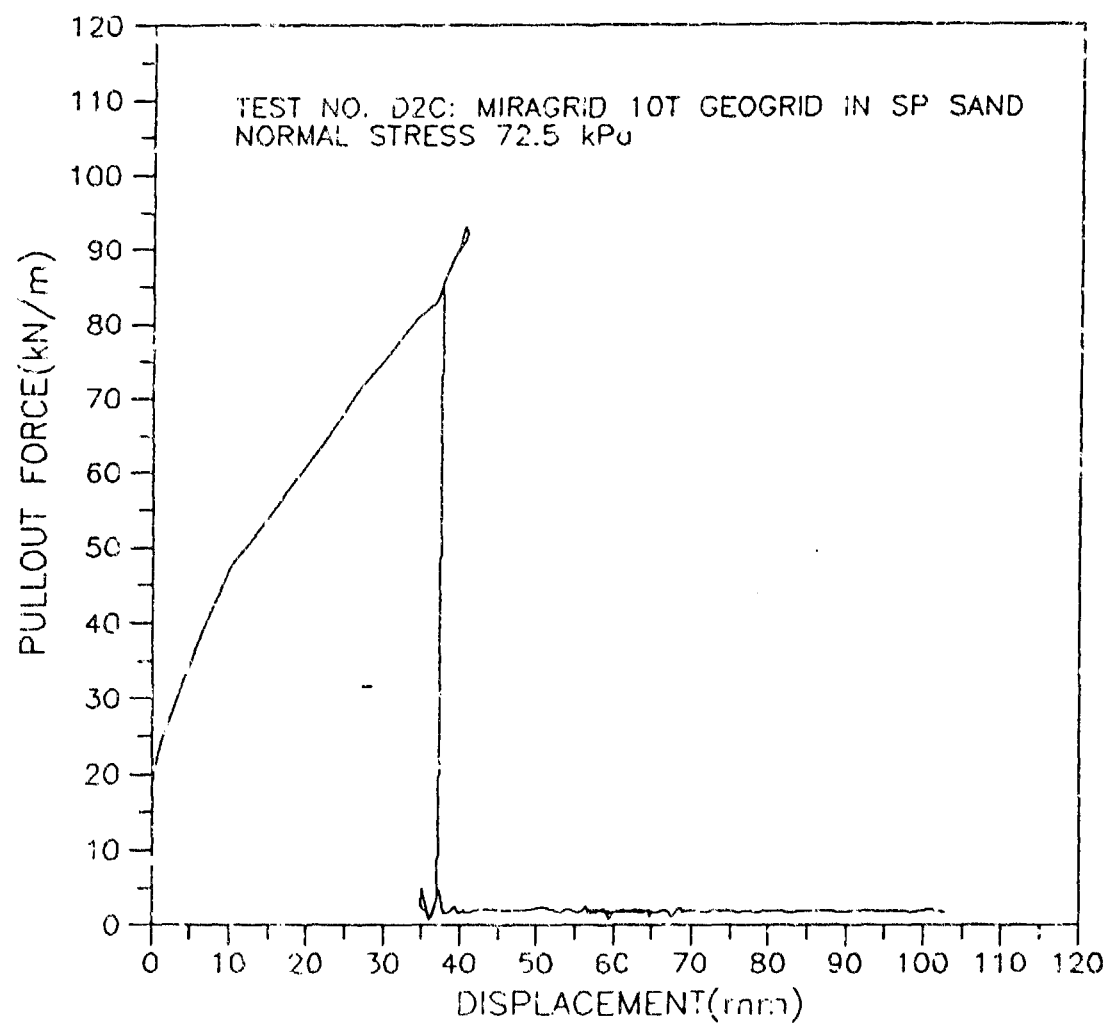
Figure 55. Dynamic Pullout Response of Miragrid 10T Geogrid
for Test D2C.

60
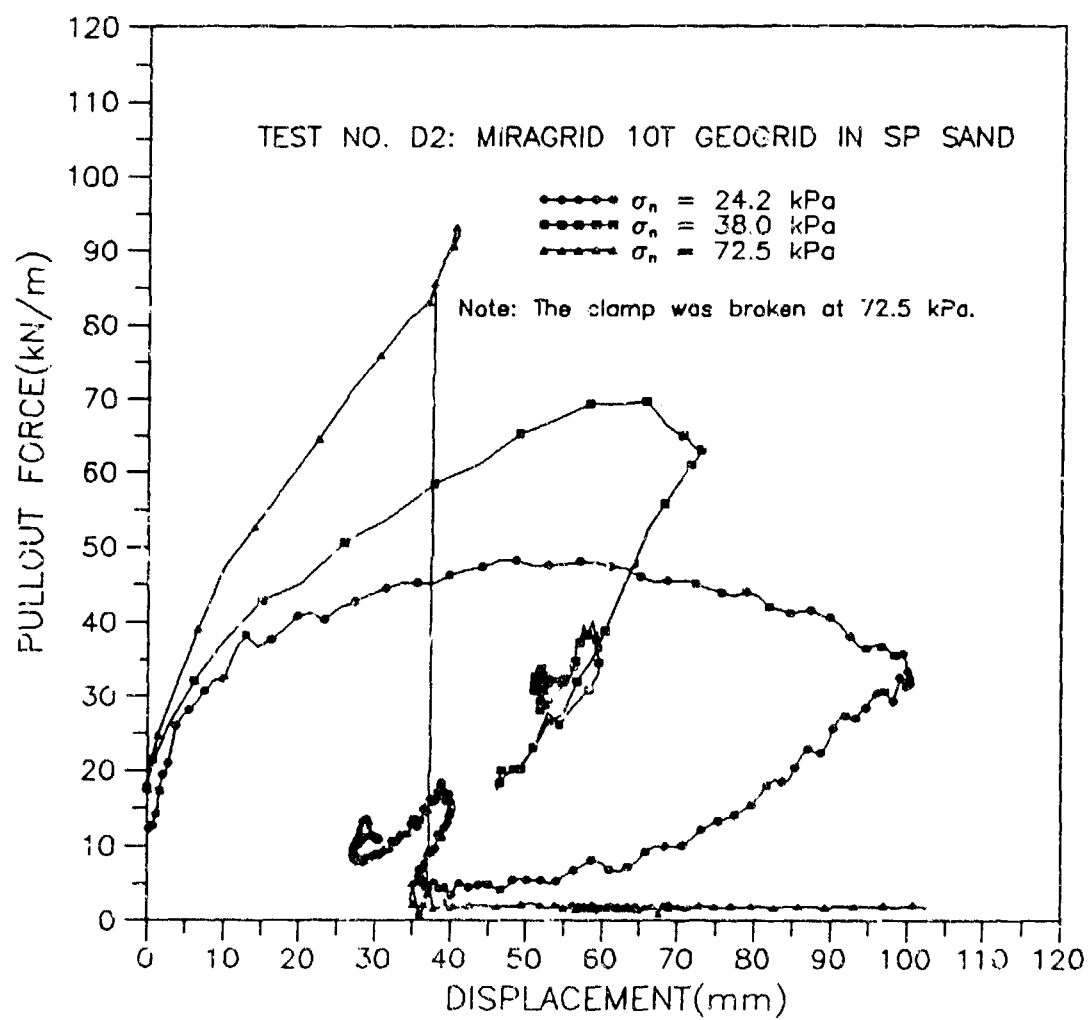
Figure 56. Dynamic Pullout Response of Miragrid 10T Geogrid for Test D2A, D2B, and D2C.

61

Figure 57.   Measured Acceleration at Pulling End of Matrex 120
Geogrid for Test D3A.

62
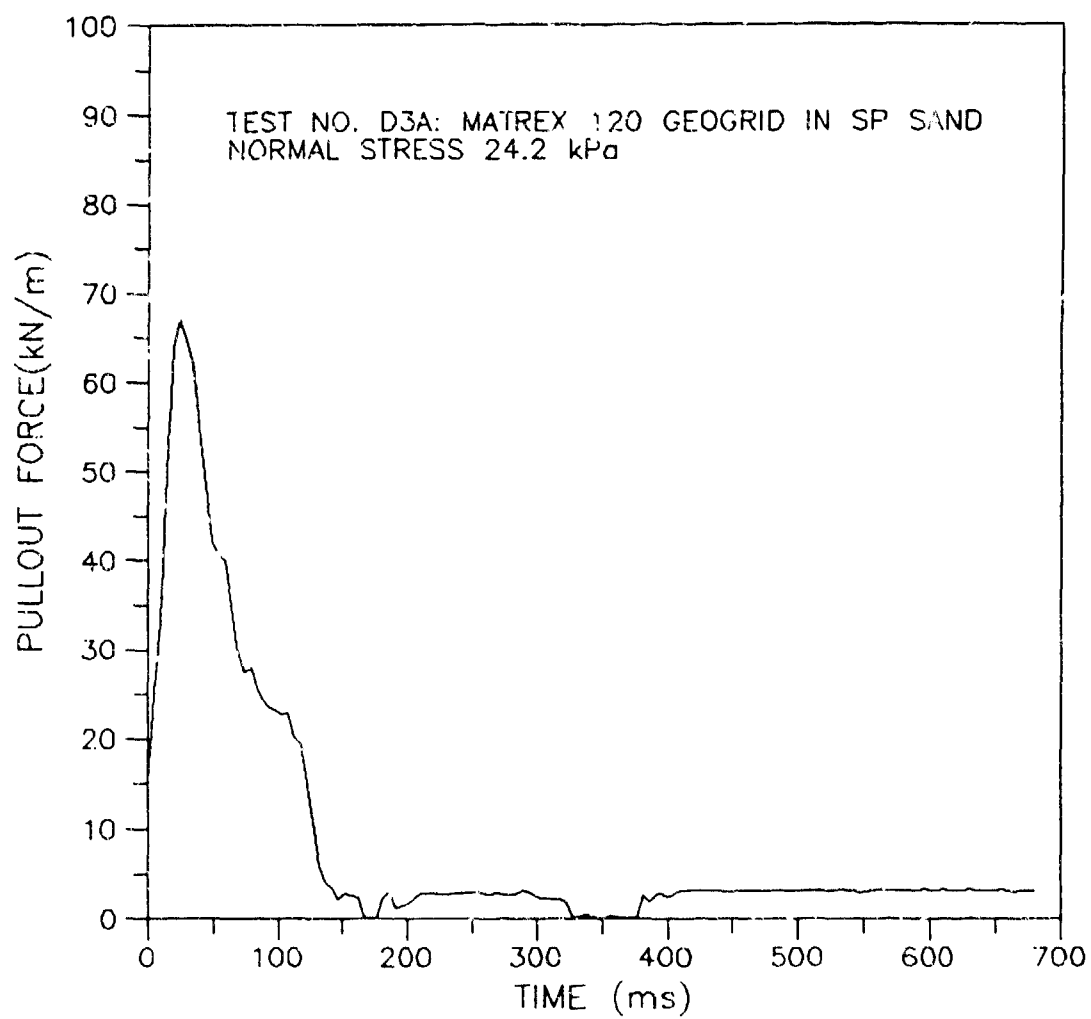
Figure 58.   Measured Force at Pulling End of Matrex 120 Geogrid
for Test D3A.

63
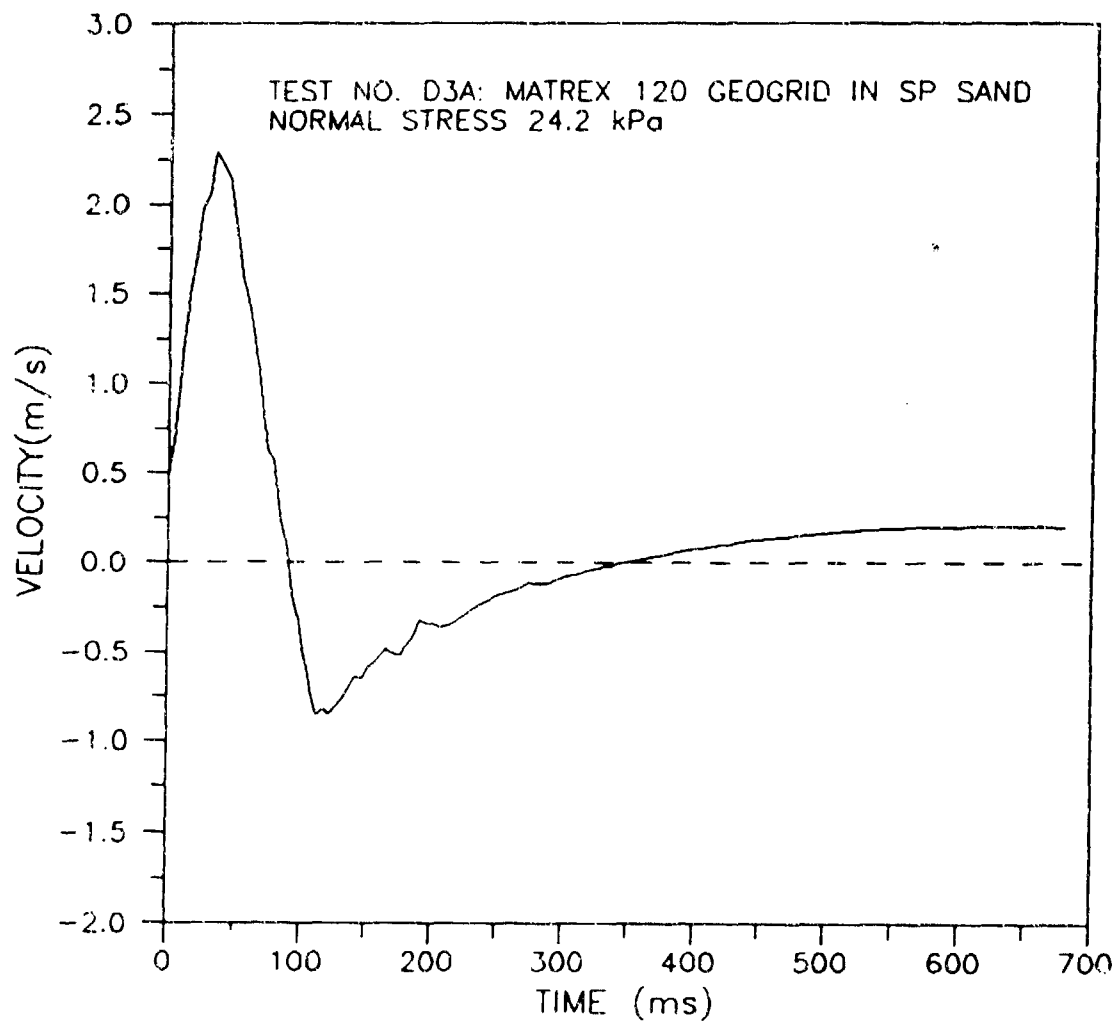
Figure 59.   Velocity Time History at Pulling End of Matrex 120
             Geogrid for Test D3A.
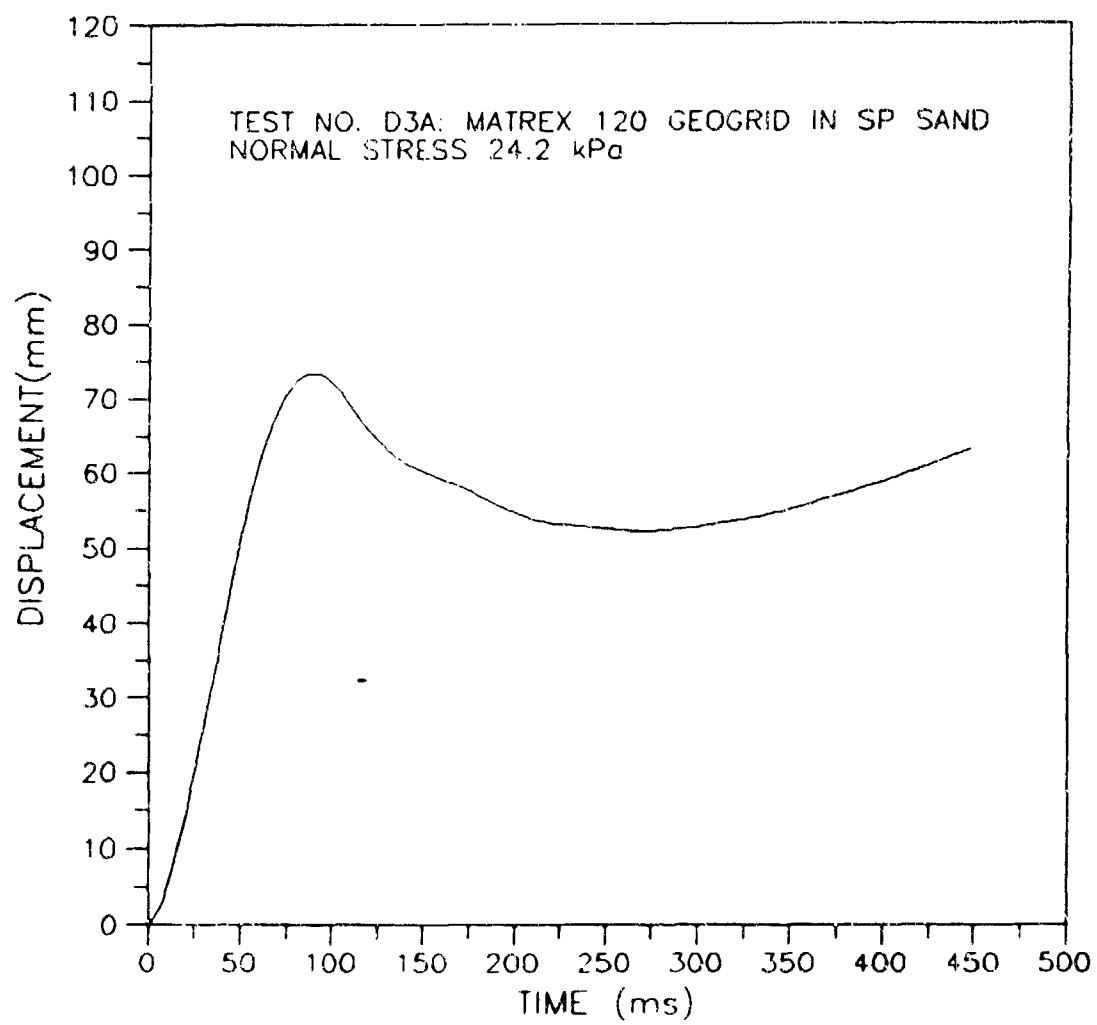
Figure 60.   Displacement Time History at Pulling End of Matrex 120
             Geogrid for Test D3A.

65
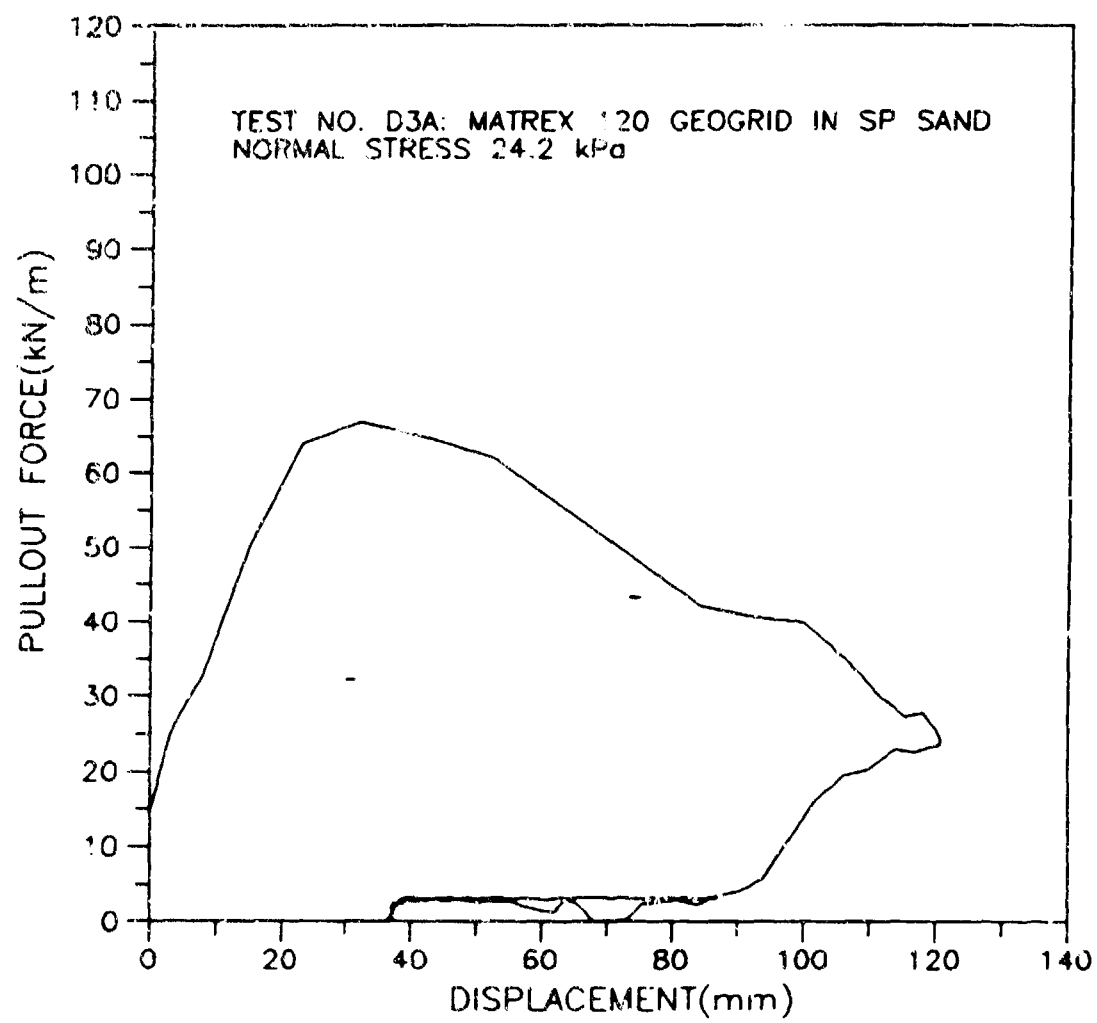
Figure 51. Dynamic Pullout Response of Matrex 120 Geogrid for Test D3A.

66
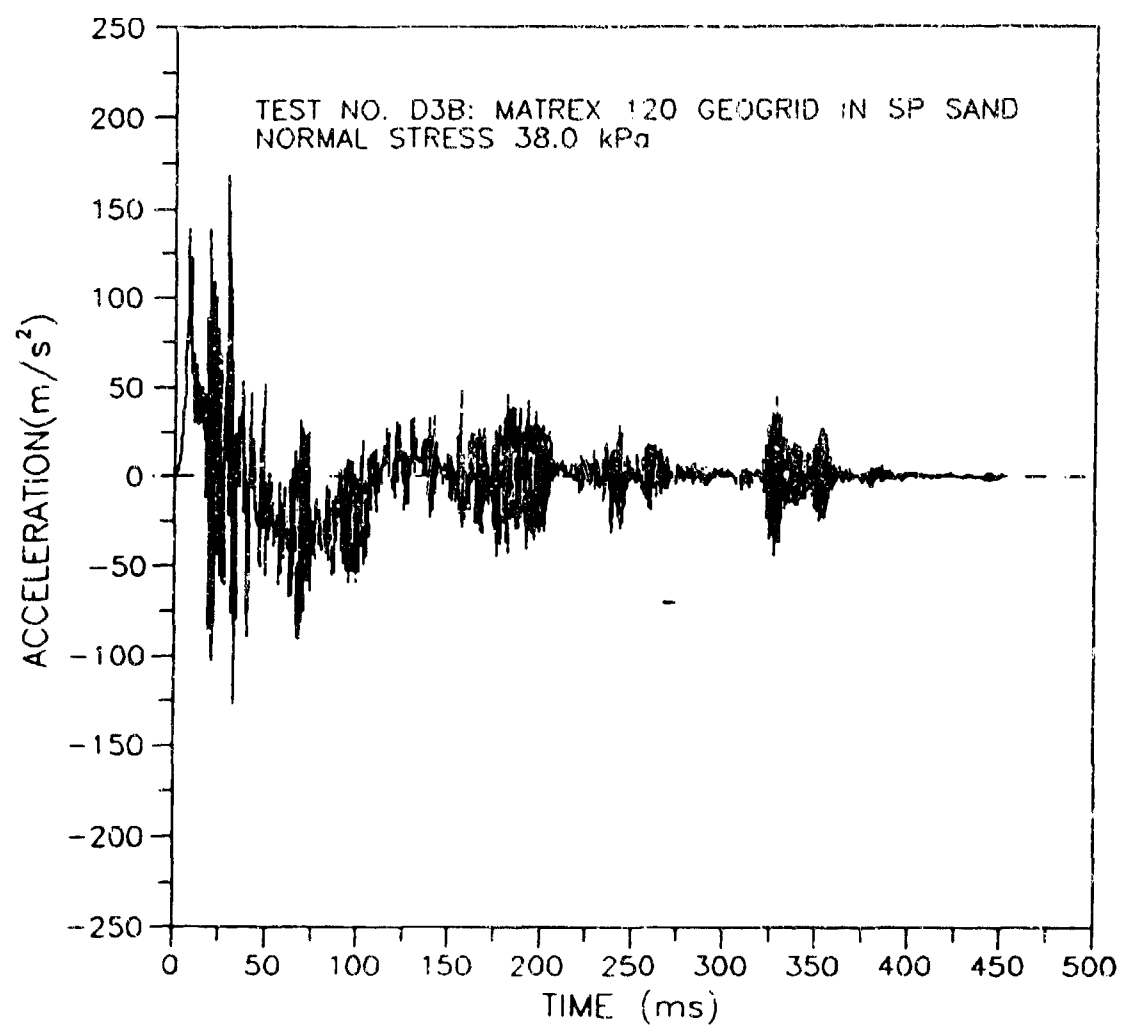
Figure 62. Measured Acceleration at Pulling End of Matrex 120 Geogrid for Test D3B.

67
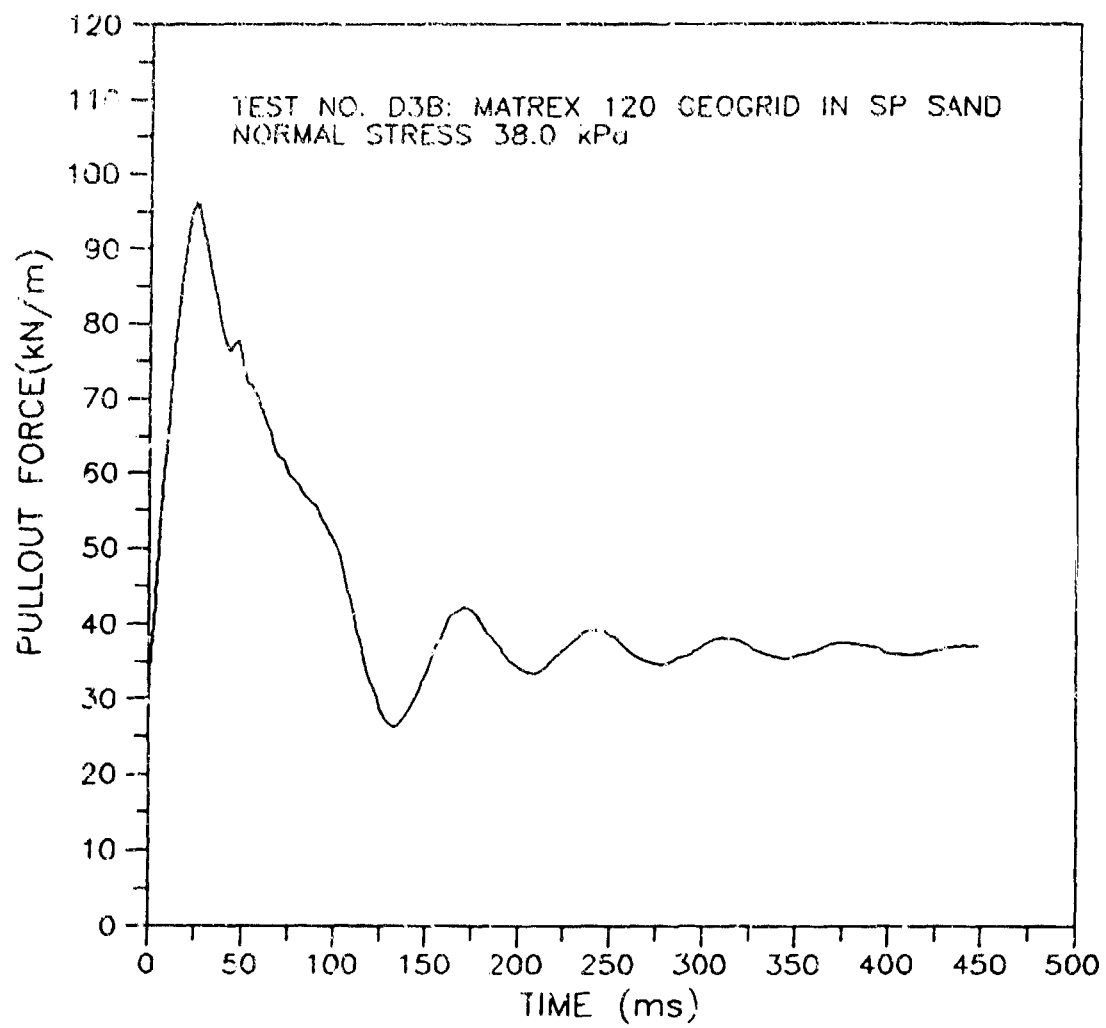
Figure 63. Measured Force at Pulling End of Matrex 120 Geogrid for Test D3B.

68
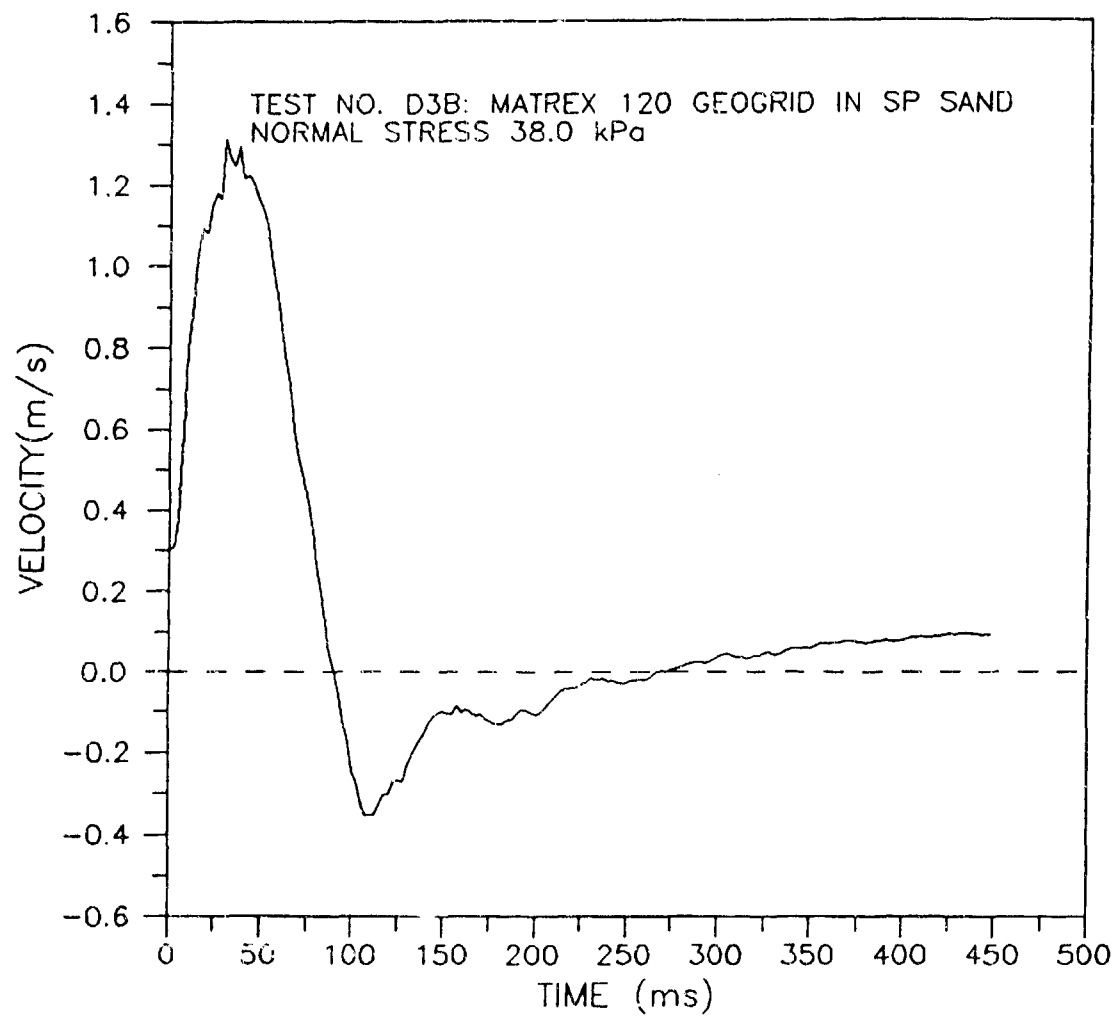
Figure 64.   Velocity Time History at Pulling End of Matrex 120
            Geogrid for Test D3B.

69
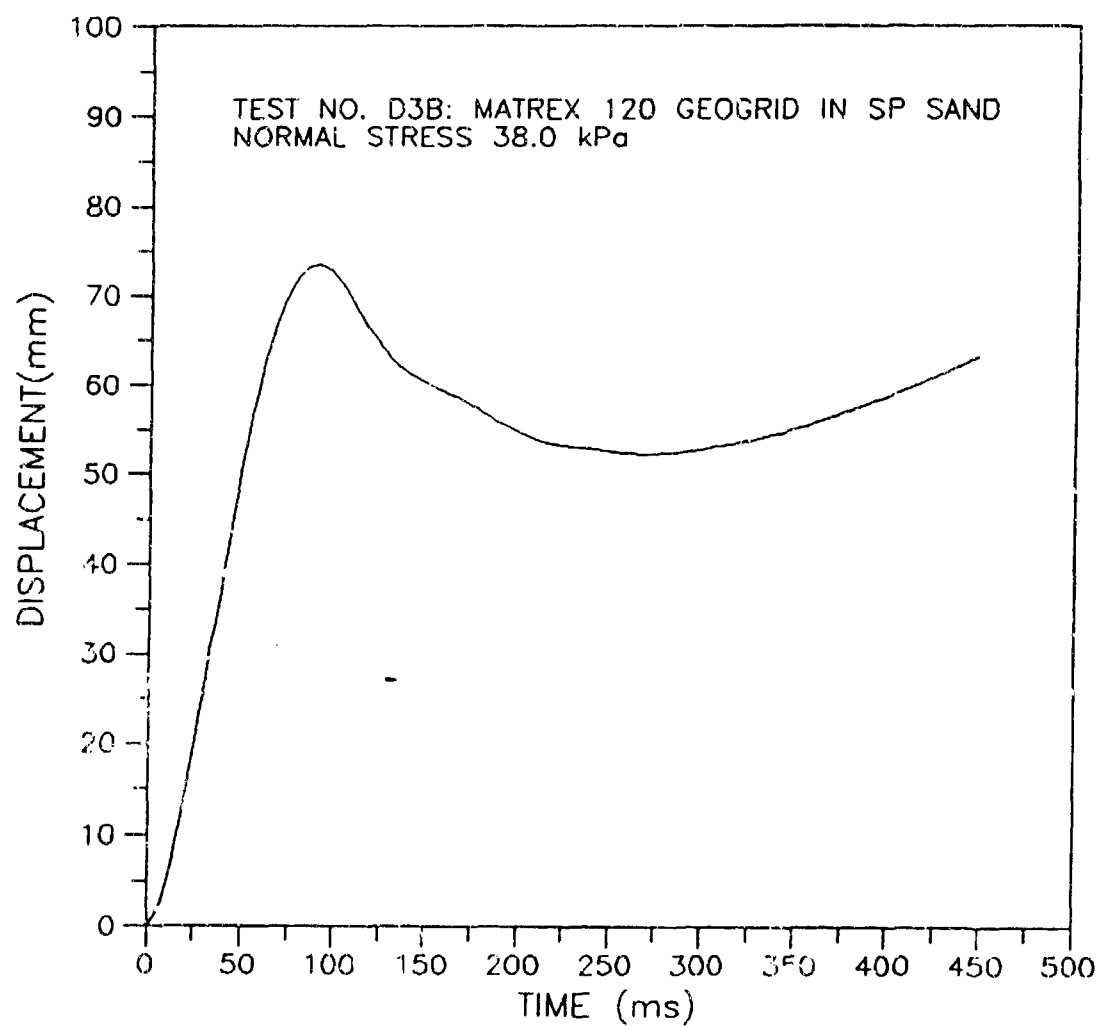
Figure 65. Displacement Time History at Pulling End of Matrex 120 Geogrid for Test D3B.

70
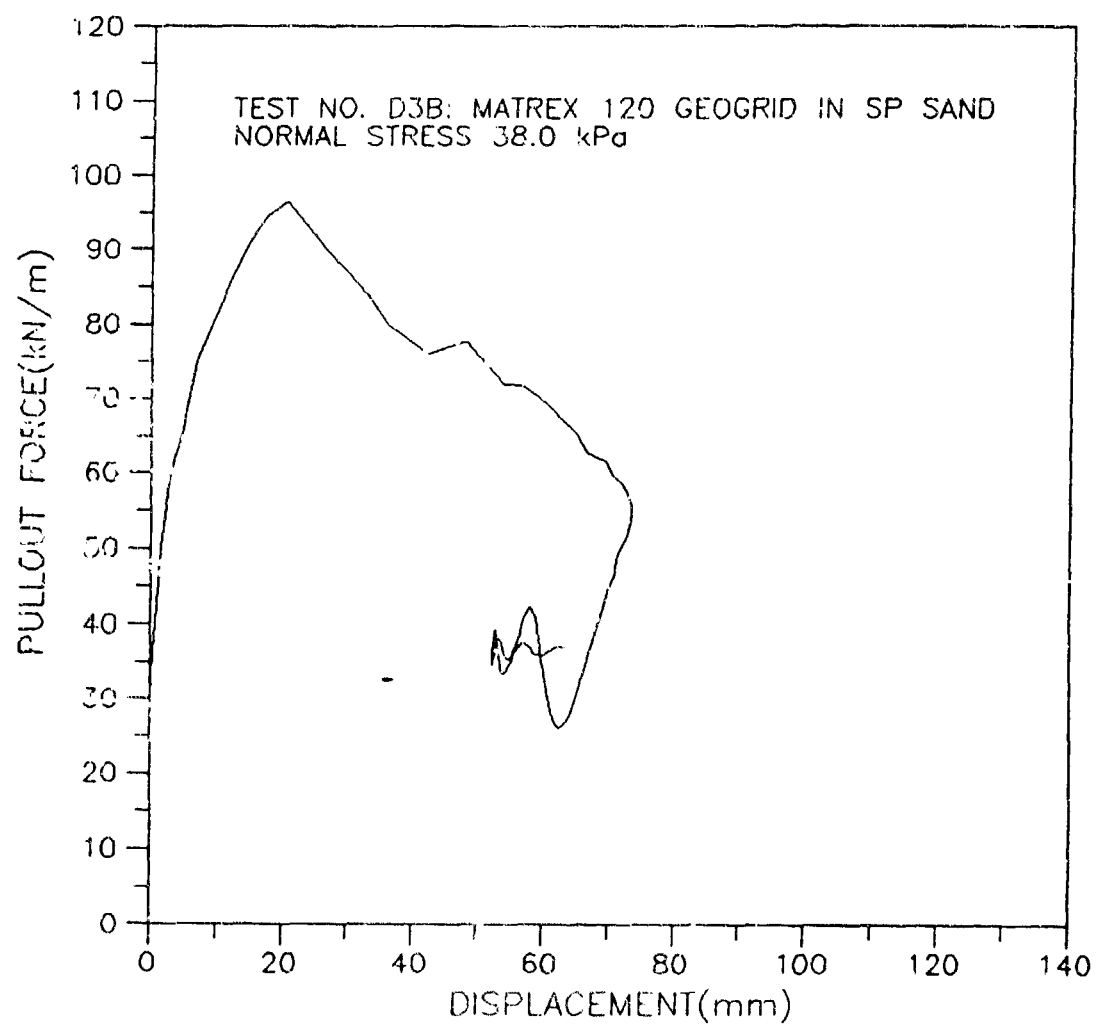
Figure 66. Dynamic Pullout Response of Matrex 120 Geogrid
for Test D3B.
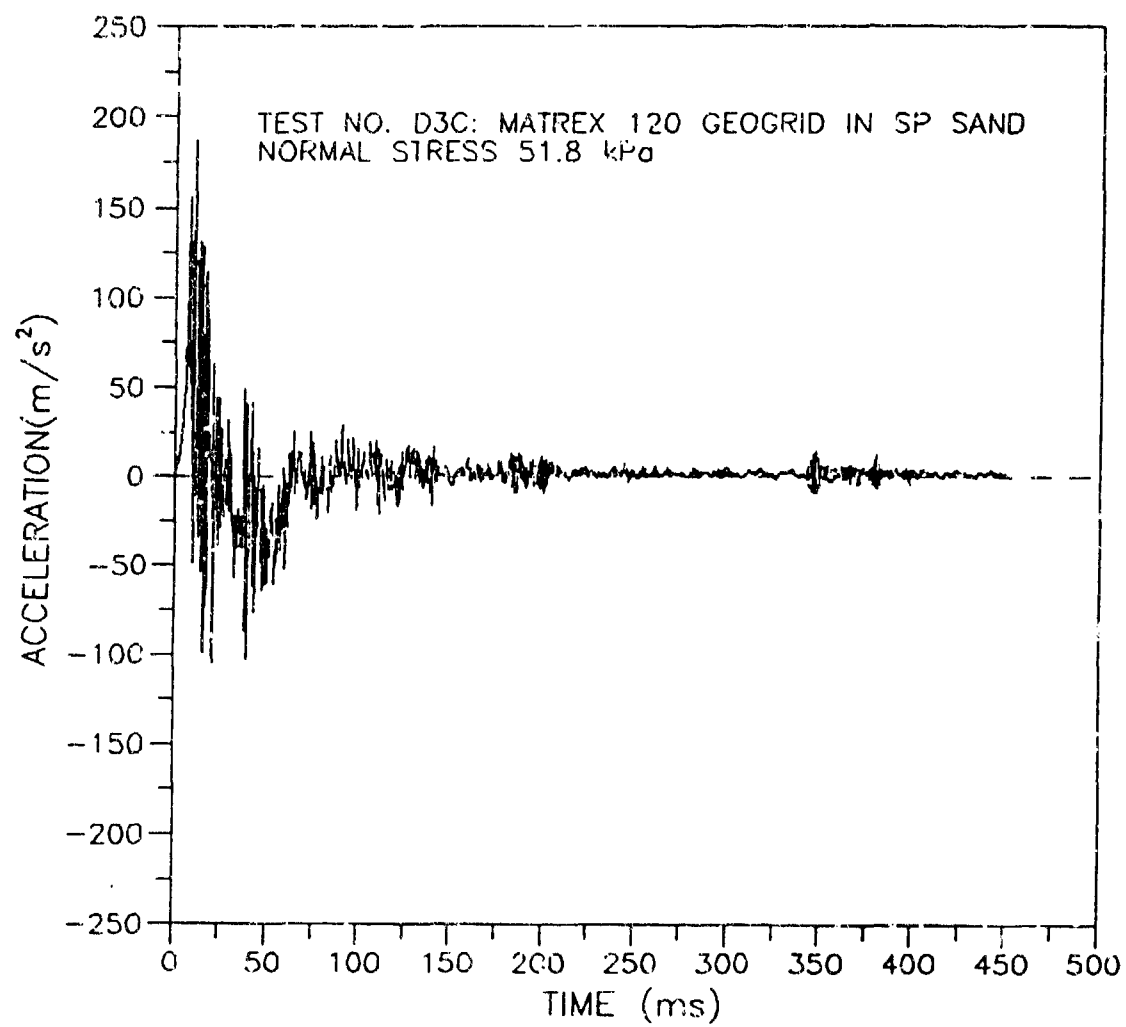
71

Figure 57. Measured Acceleration at Pulling End of Matrex 120
Geogrid for Test D3C.

72
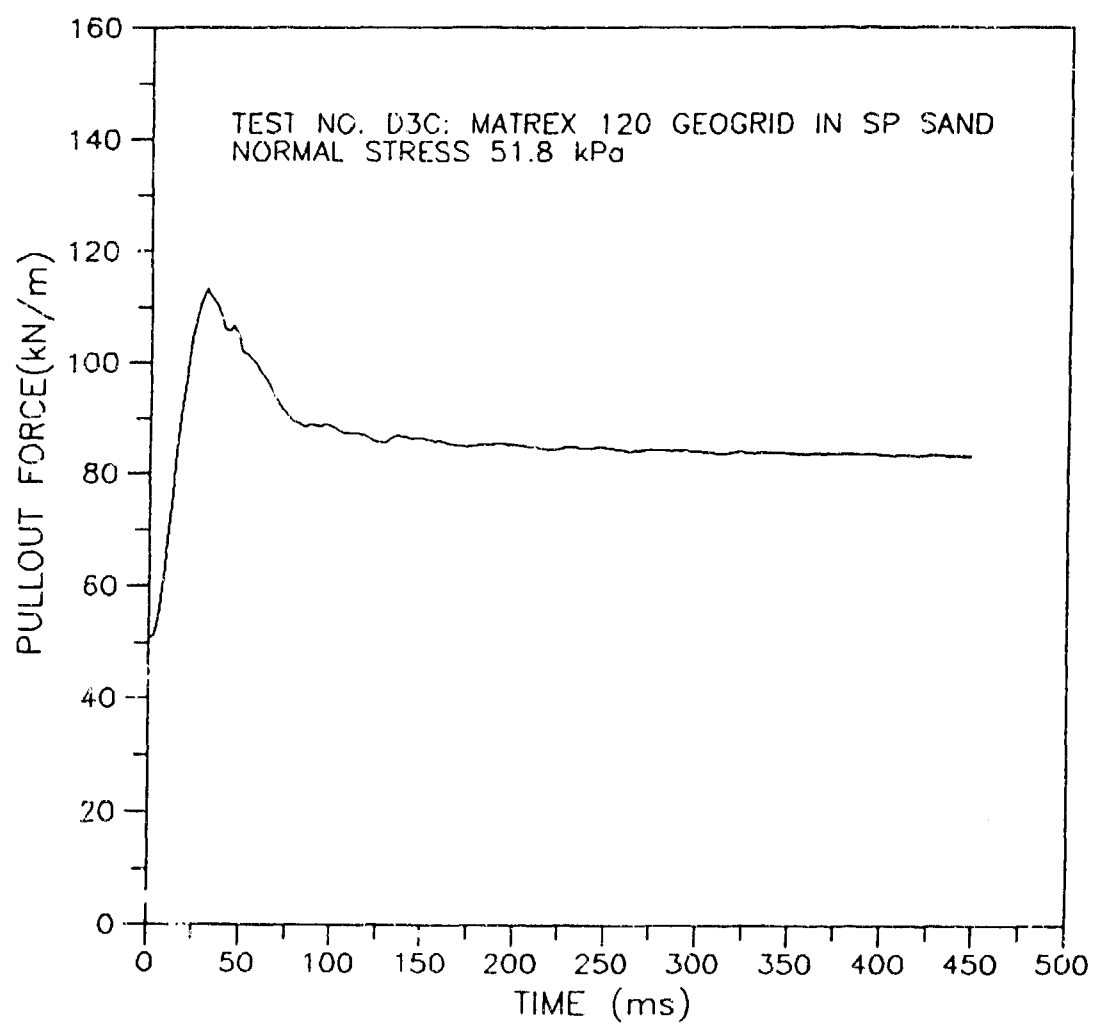
Figure 68.   Measured Force at Pulling End of Matrex 120 Geogrid
             for Test D3C.

73
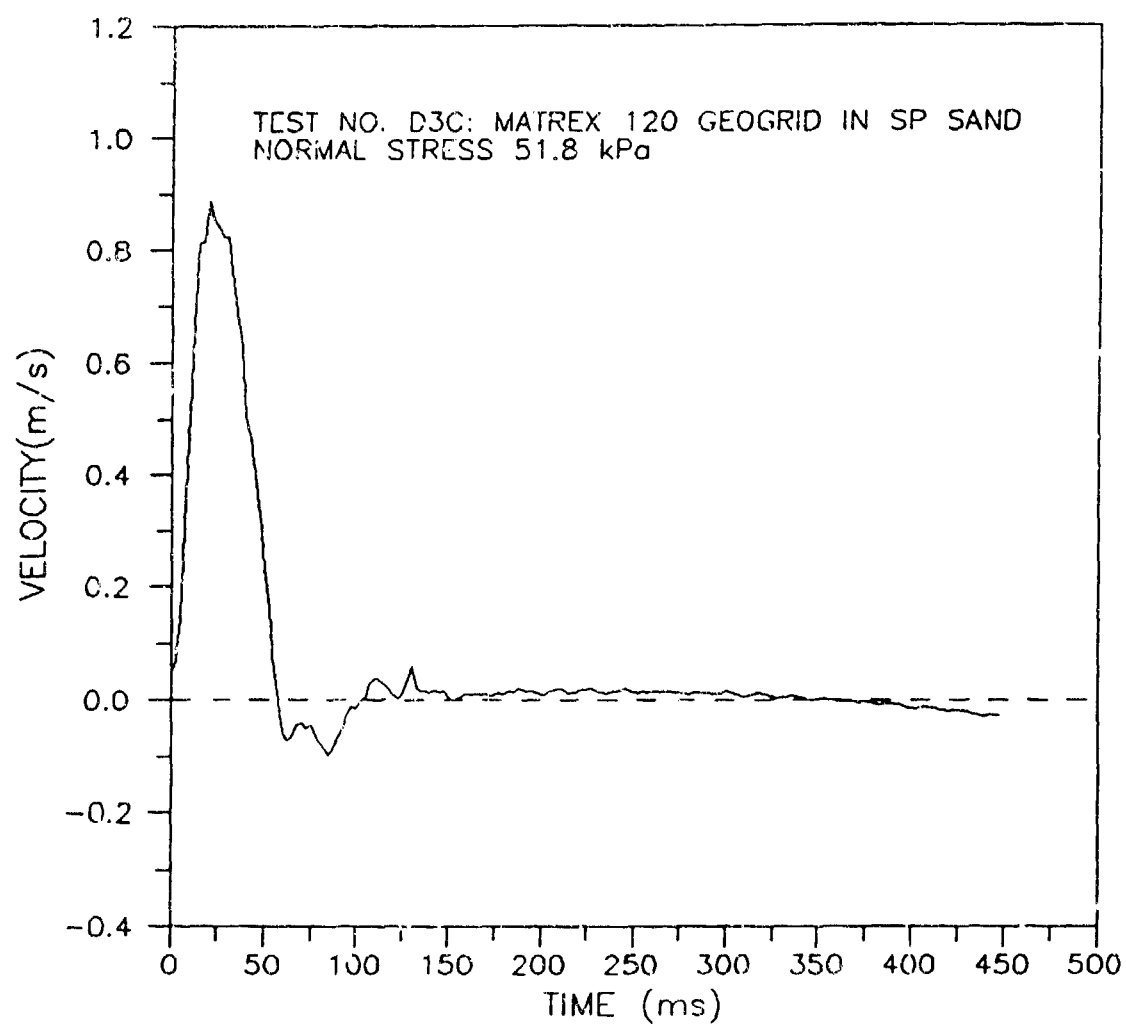
Figure 69. Velocity Time History at Pulling End of Matrex 120
Geogrid for Test D3C.

74
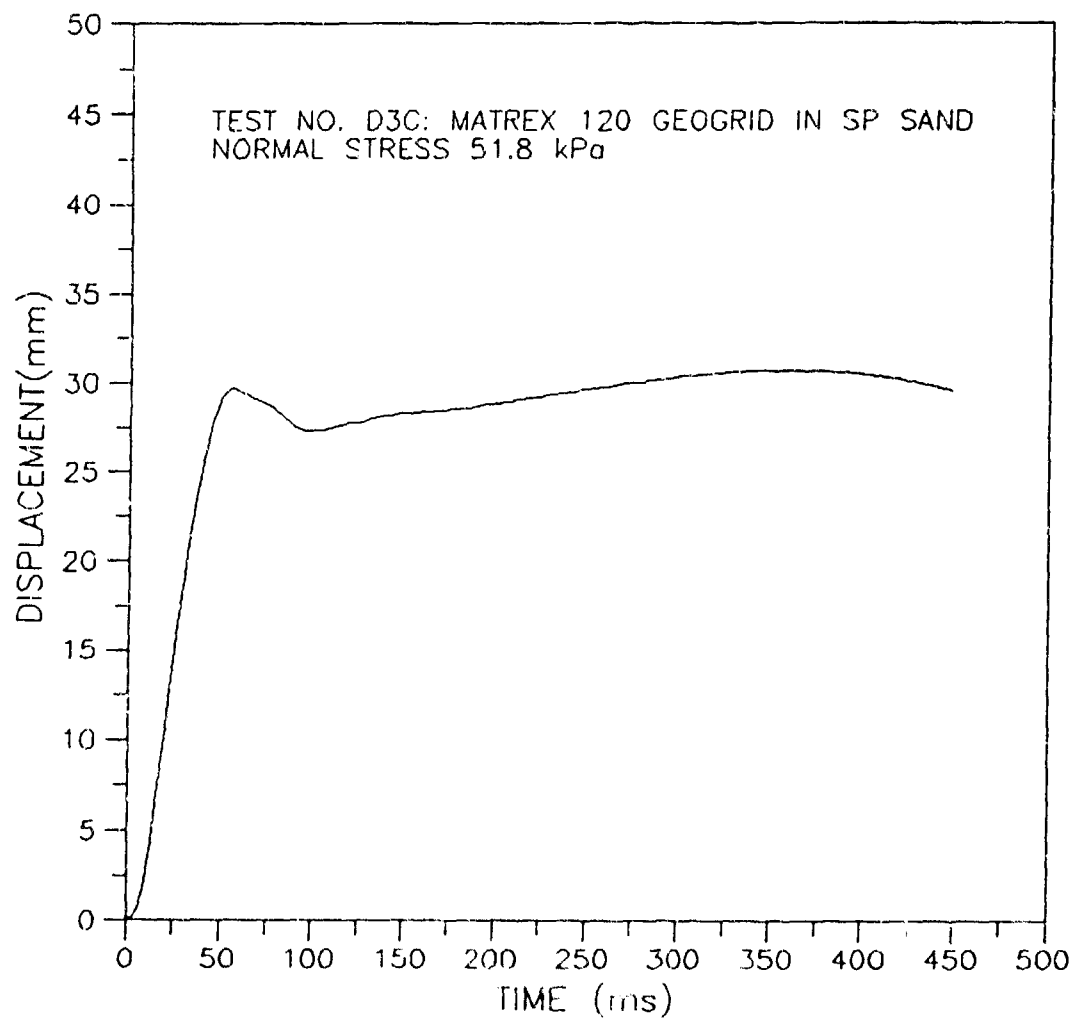
Figure 70. Displacement Time History at Pulling End of Matrex 120
Geogrid for Test D3C.

75

TEST NO. D3C: MATREX 120 GEOGRID IN SP SAND
NORMAL STRESS 51.8 kPa
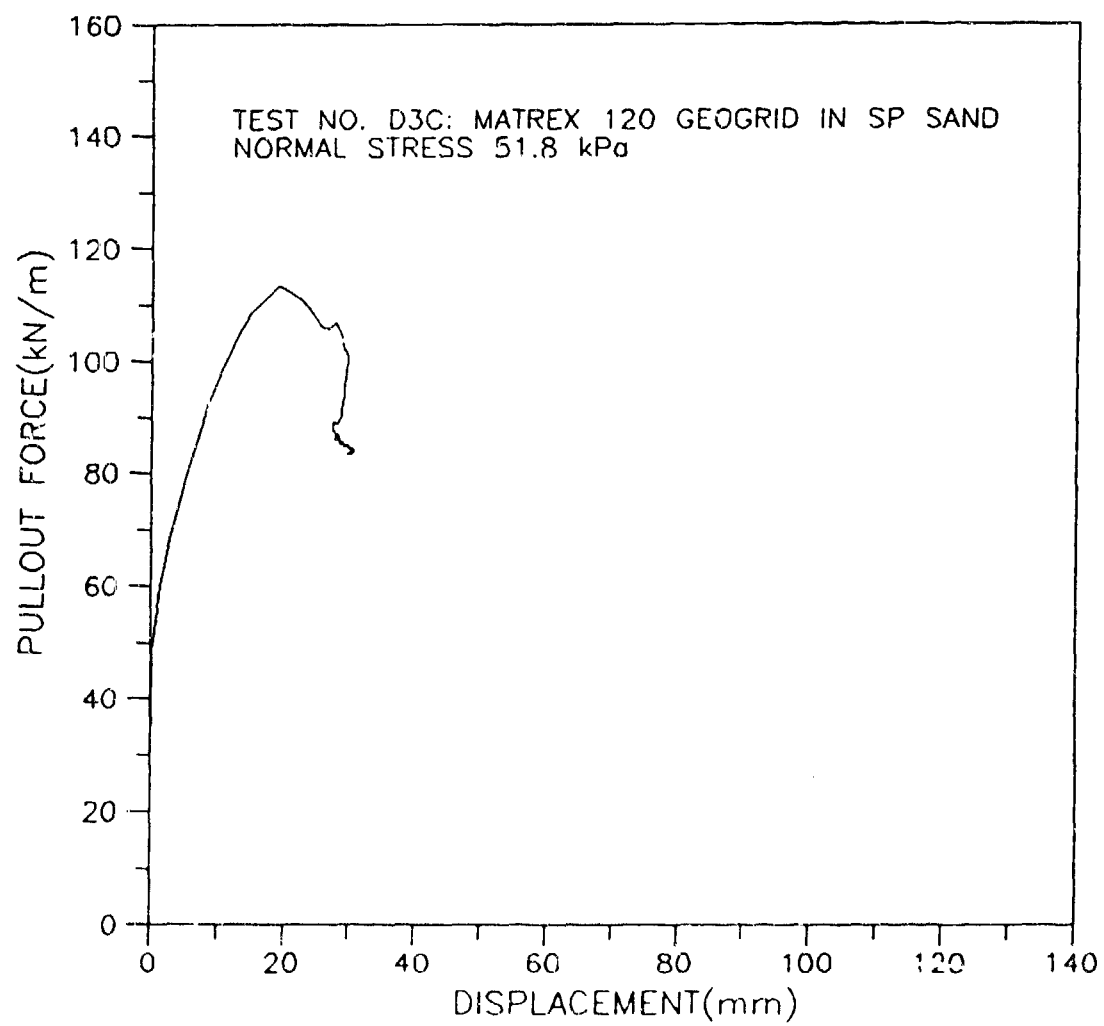
Figure 71. Dynamic Pullout Response of Matrex 120 Geogrid
for Test D3C.

76
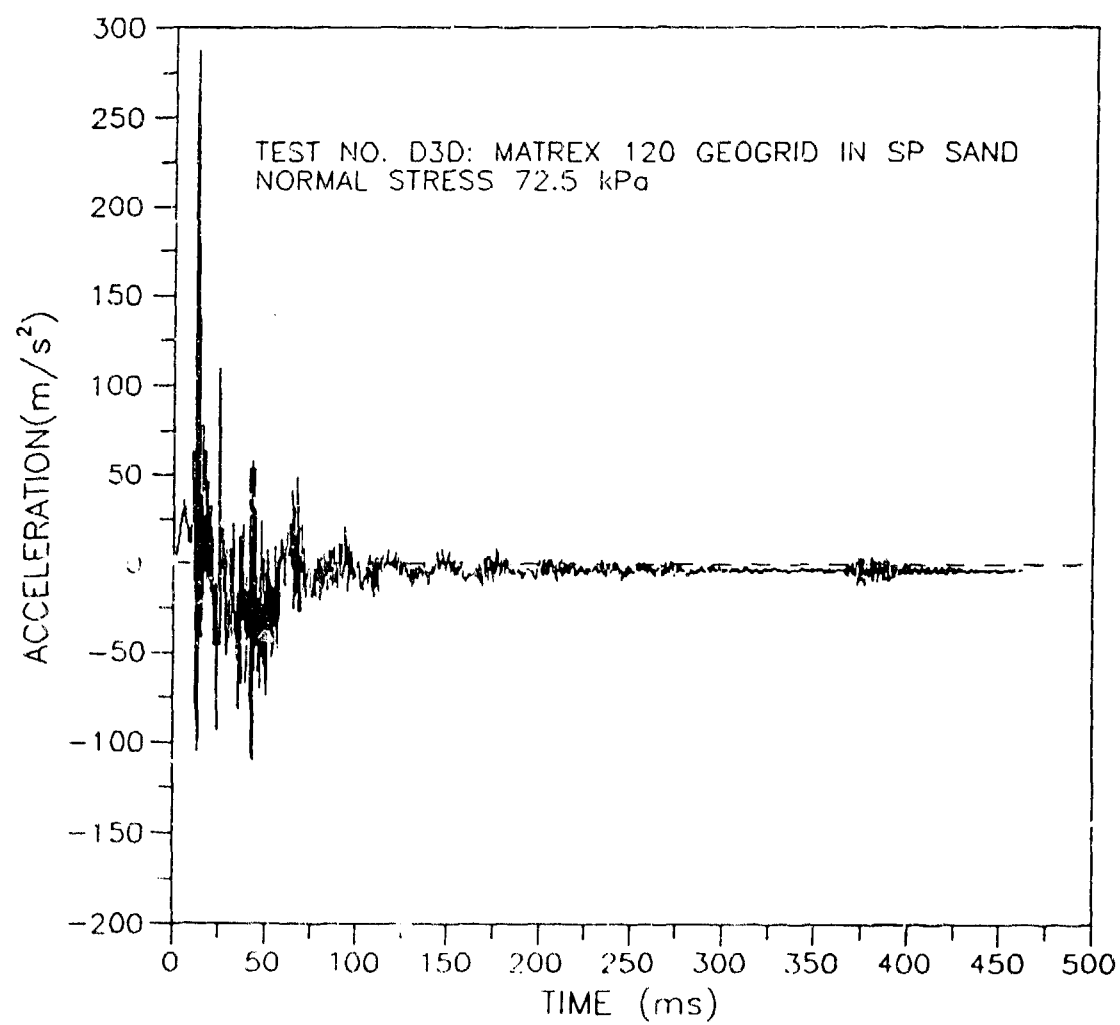
Figure 72. Measured Acceleration at Pulling End of Matrex 120 Geogrid for Test D3D.

77
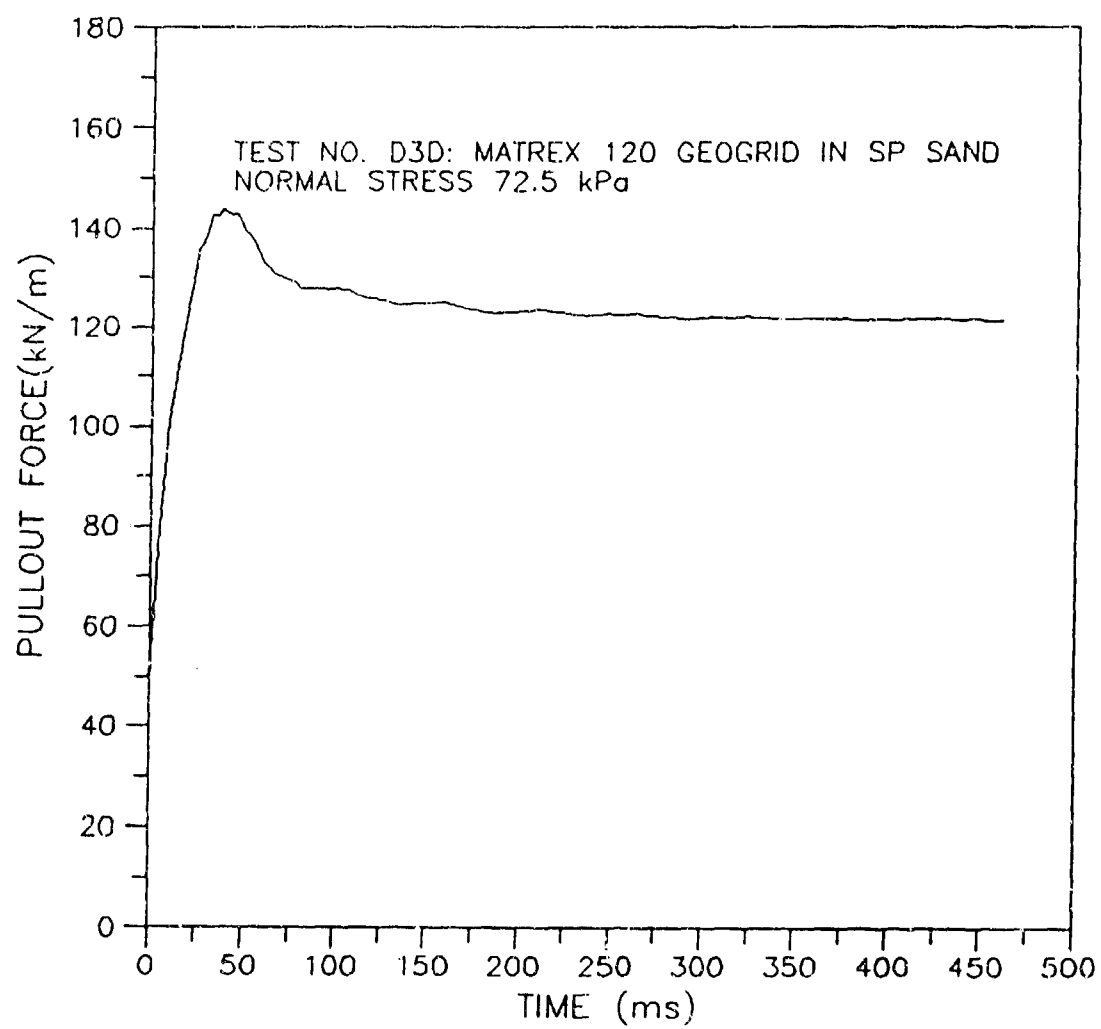
Figure 73. Measured Force at Pulling End of Matrex 120 Geogrid for Test D3D.
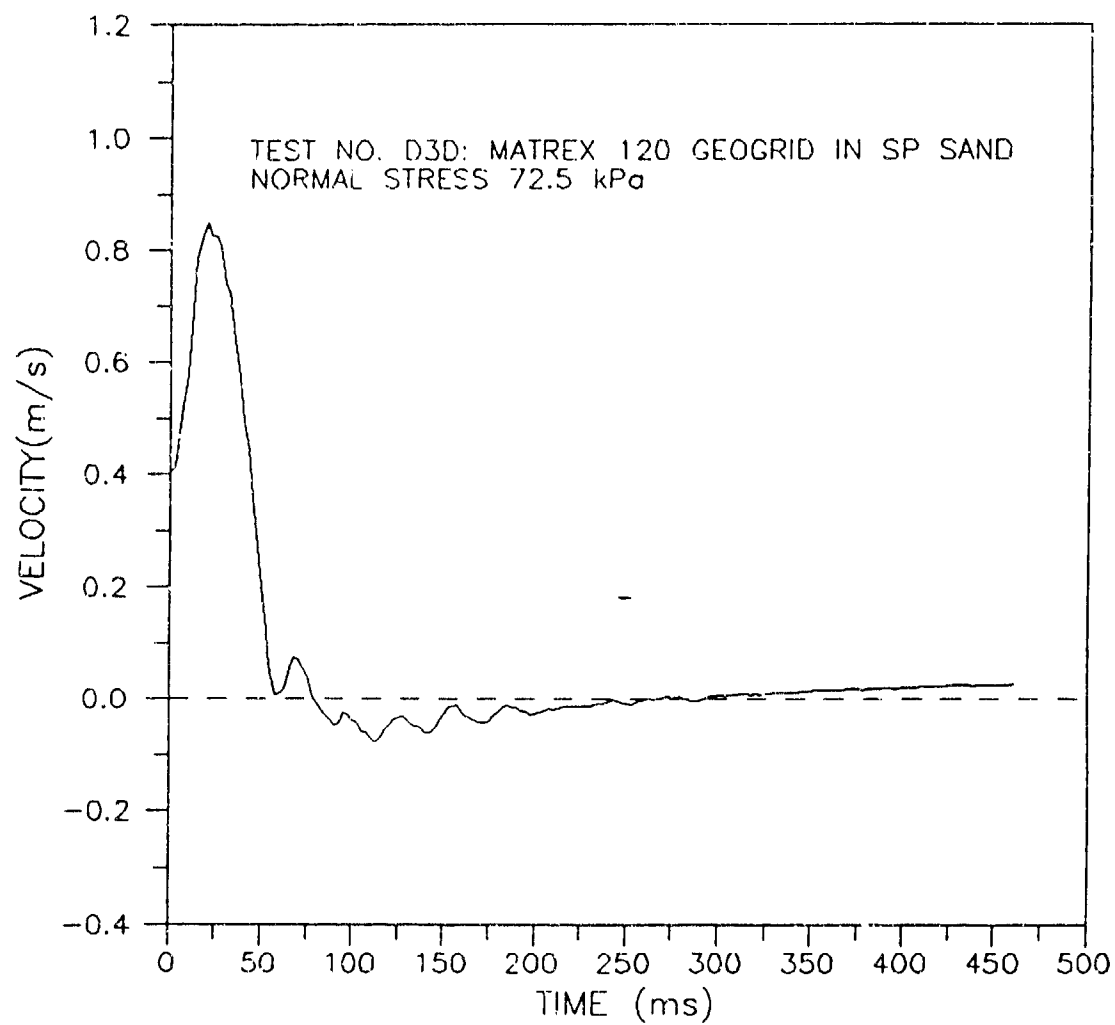
Figure 74.   Velocity Time History at Pulling End of Matrex 120
            Geogrid for Test D3D.

79

TEST NO. D3D: MATREX 120 GEOGRID IN SP SAND
NORMAL STRESS 72.5 kPa
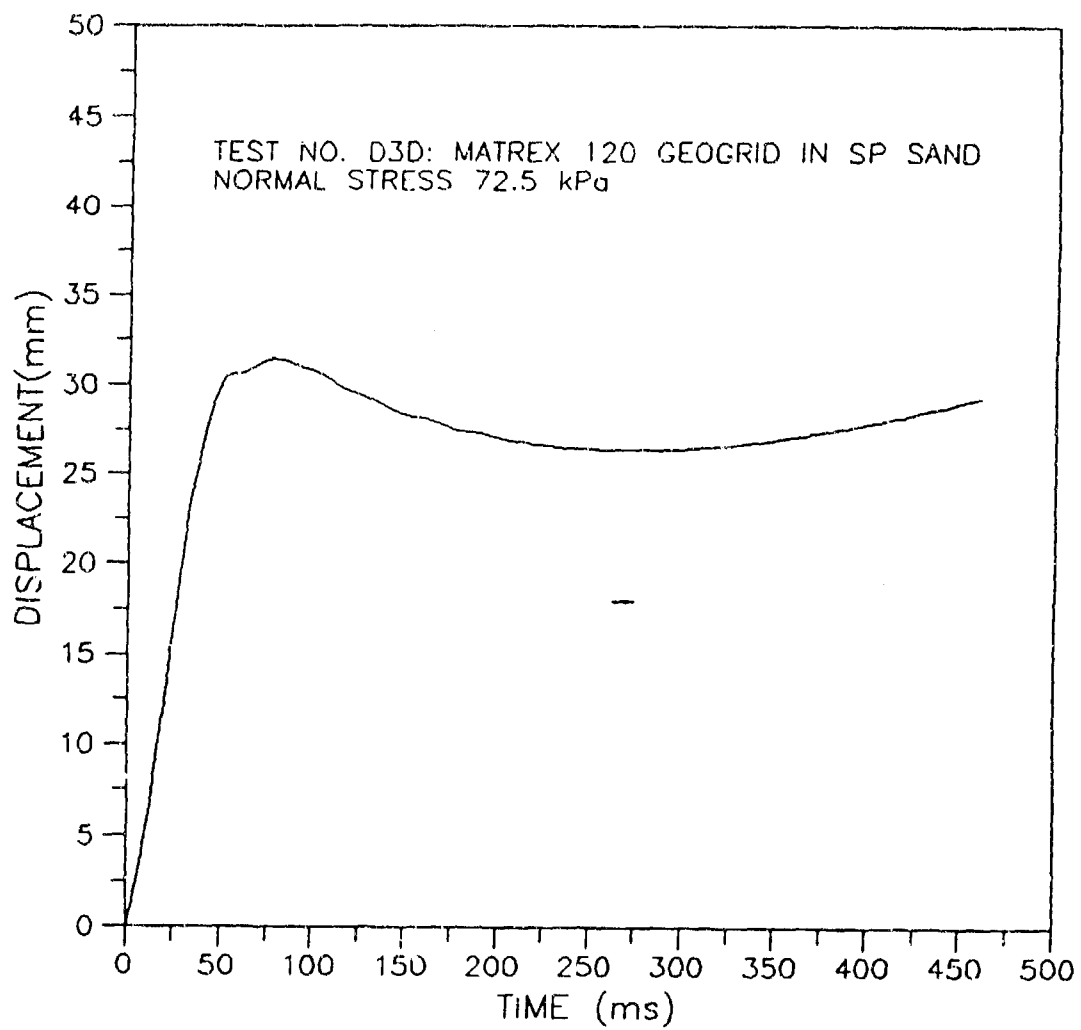
Figure 75.   Displacement Time History at Pulling End of Matrex 120
Geogrid for Test D3D.
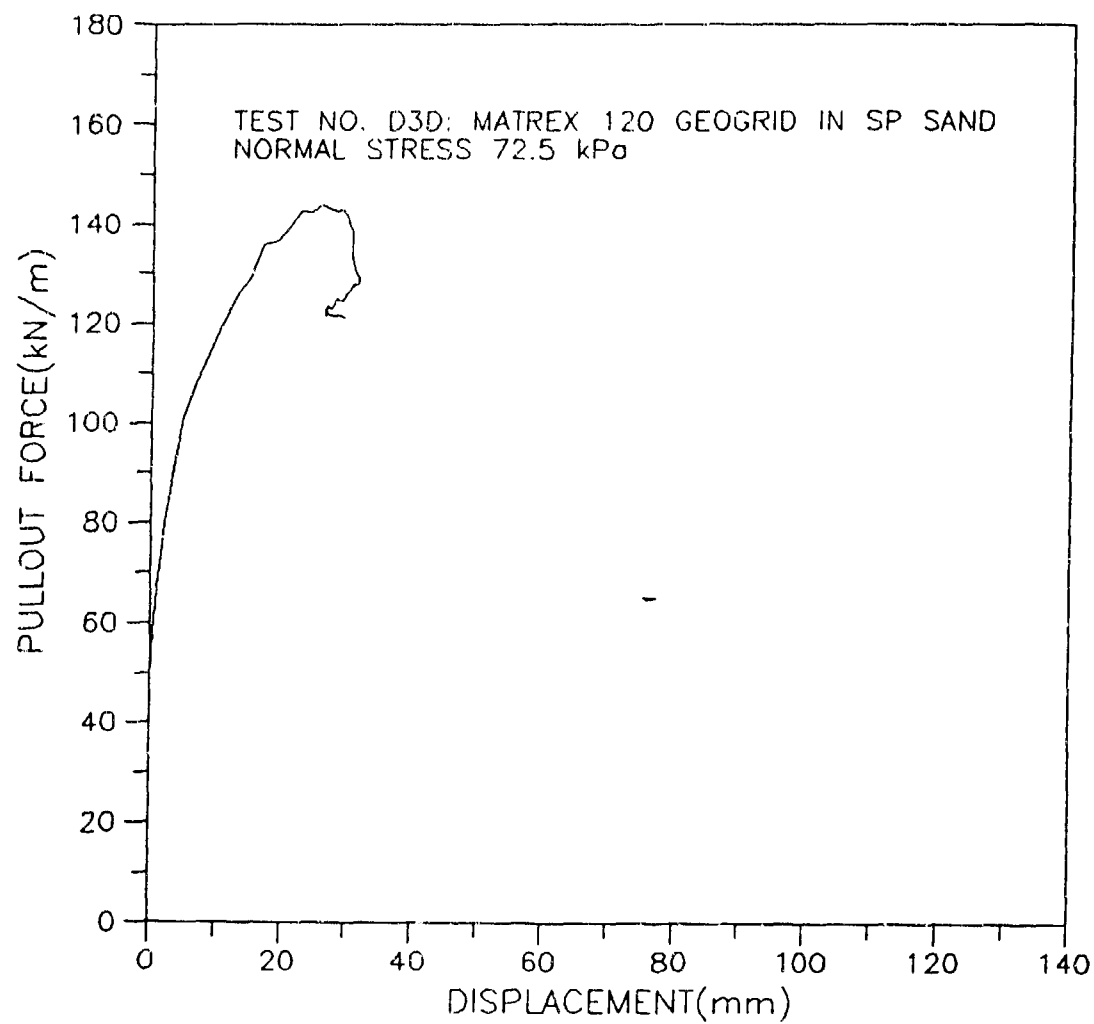
Figure 76.   Dynamic Pullout Response of Matrex 120 Geogrid
             for Test D3D.

81
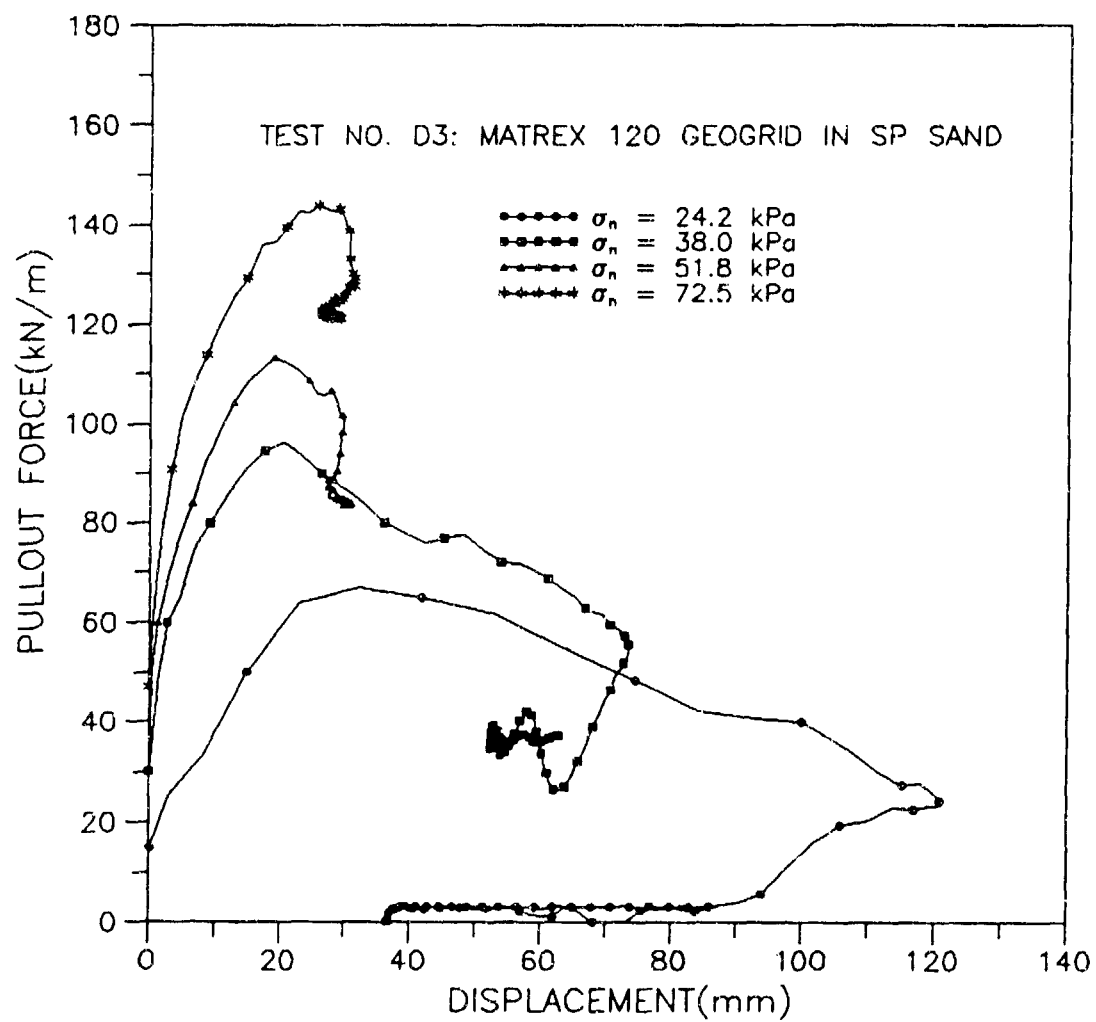
Figure 77.   Dynamic Pullout Response of M   ex 120 Geogrid
for Test D3A, D3B, D3C and D3D.

82
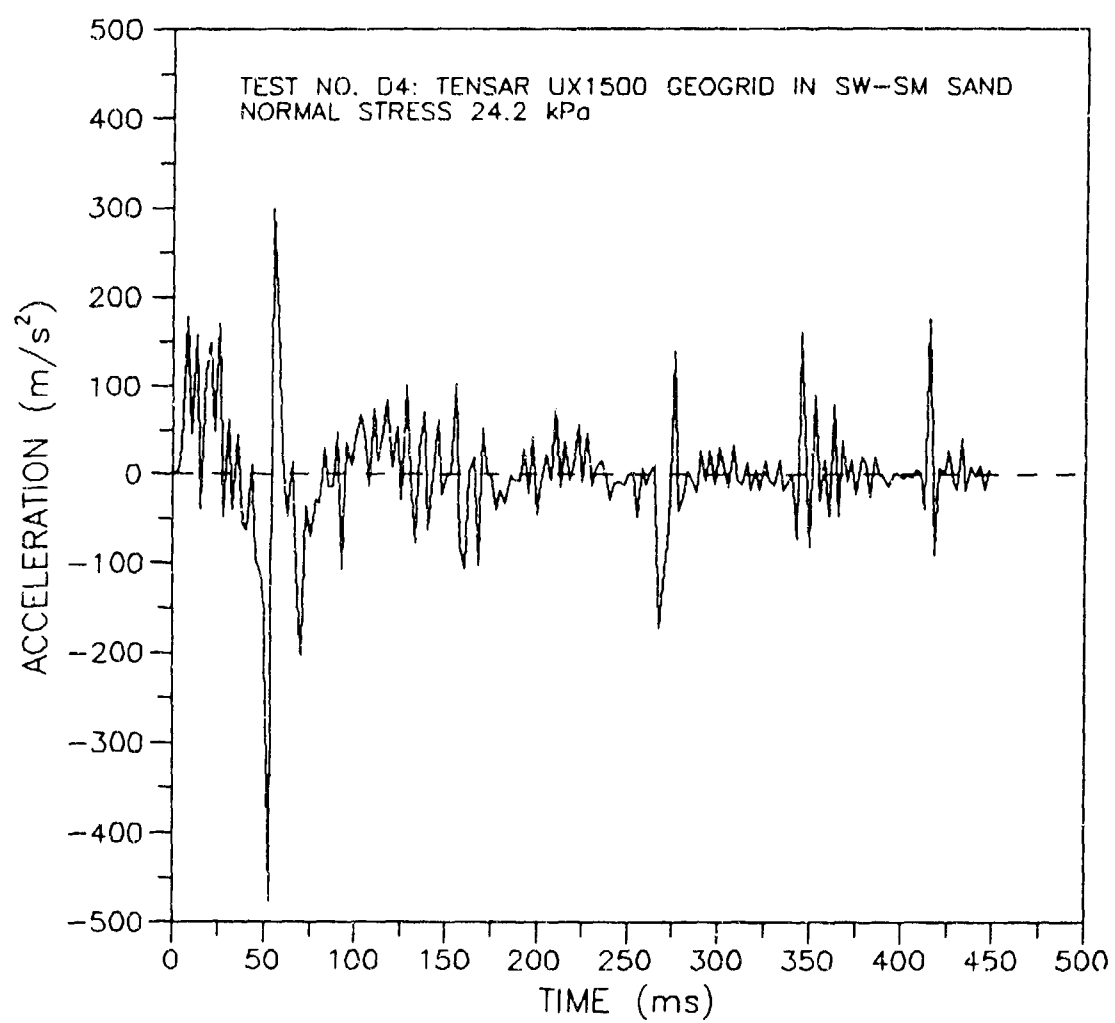
Figure 78.   Measured Acceleration at Pulling End of Tensar UX1500
Geogrid for Test D4.

83
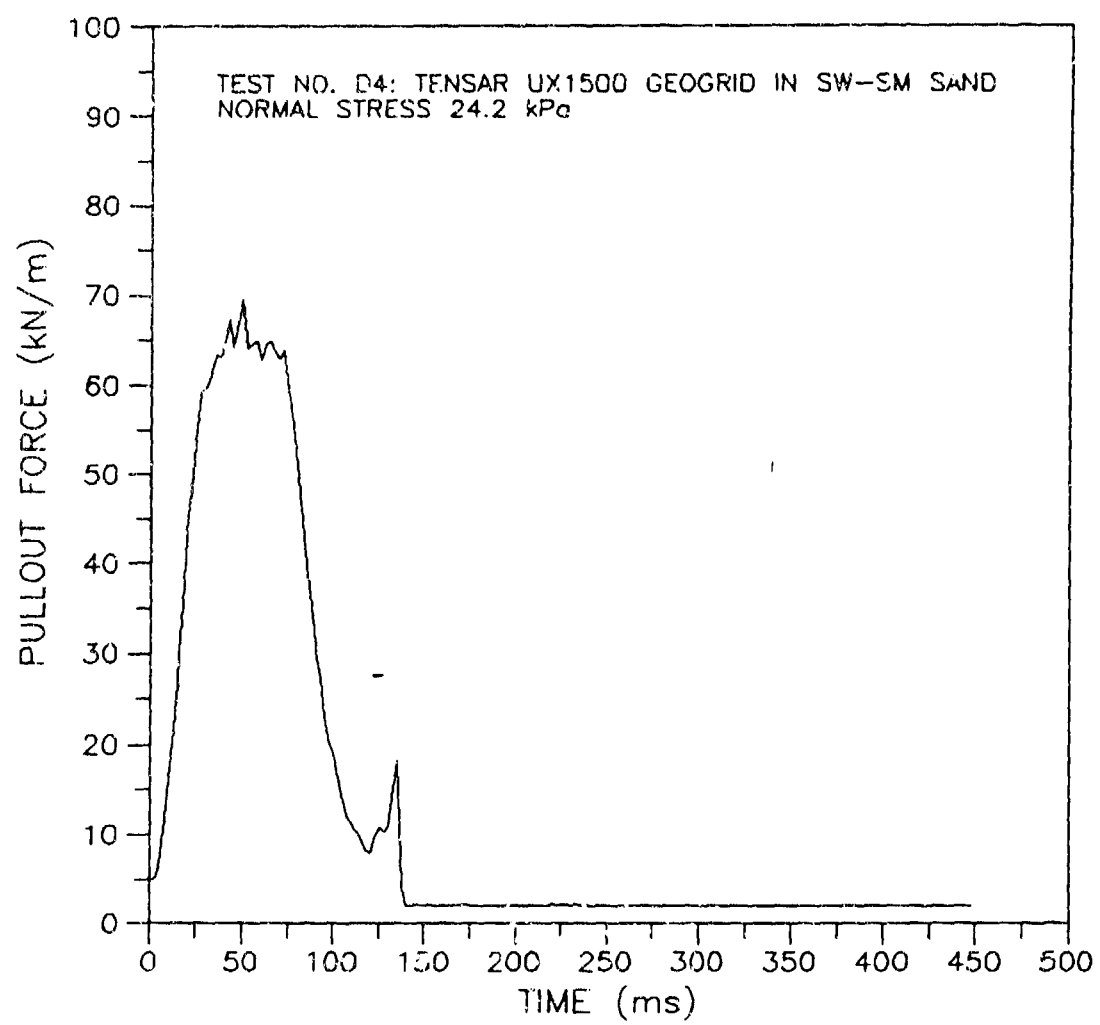
Figure 79. Measured Force at Pulling End of Tensar UX1500 Geogrid for Test D4.

84
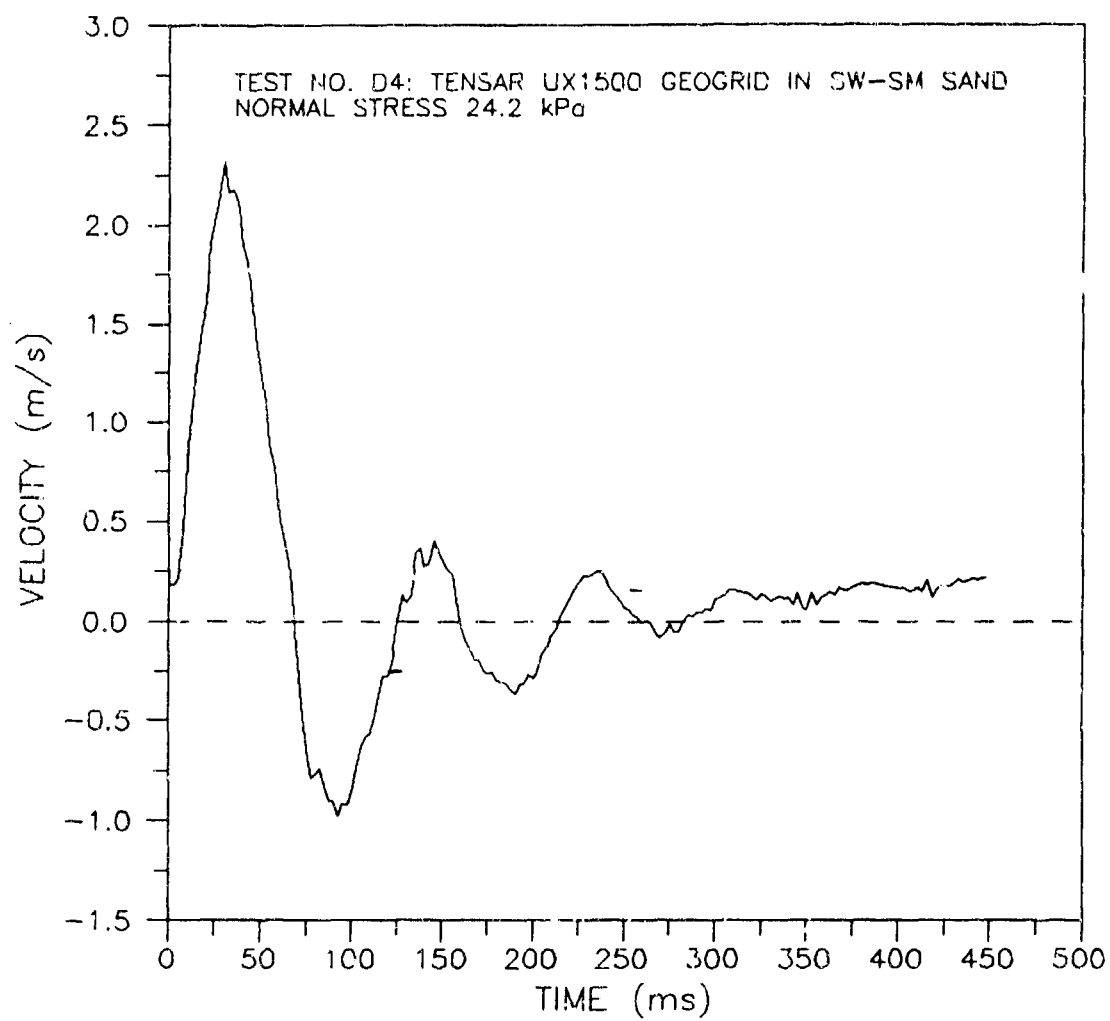
Figure 80. Velocity Time History at Pulling End of Tensar UX1500 Geogrid for Test D4.

TEST NO. D4: TENSAR UX1500 GEOGRID IN SW-SM SAND
NORMAL STRESS 24.2 kPa
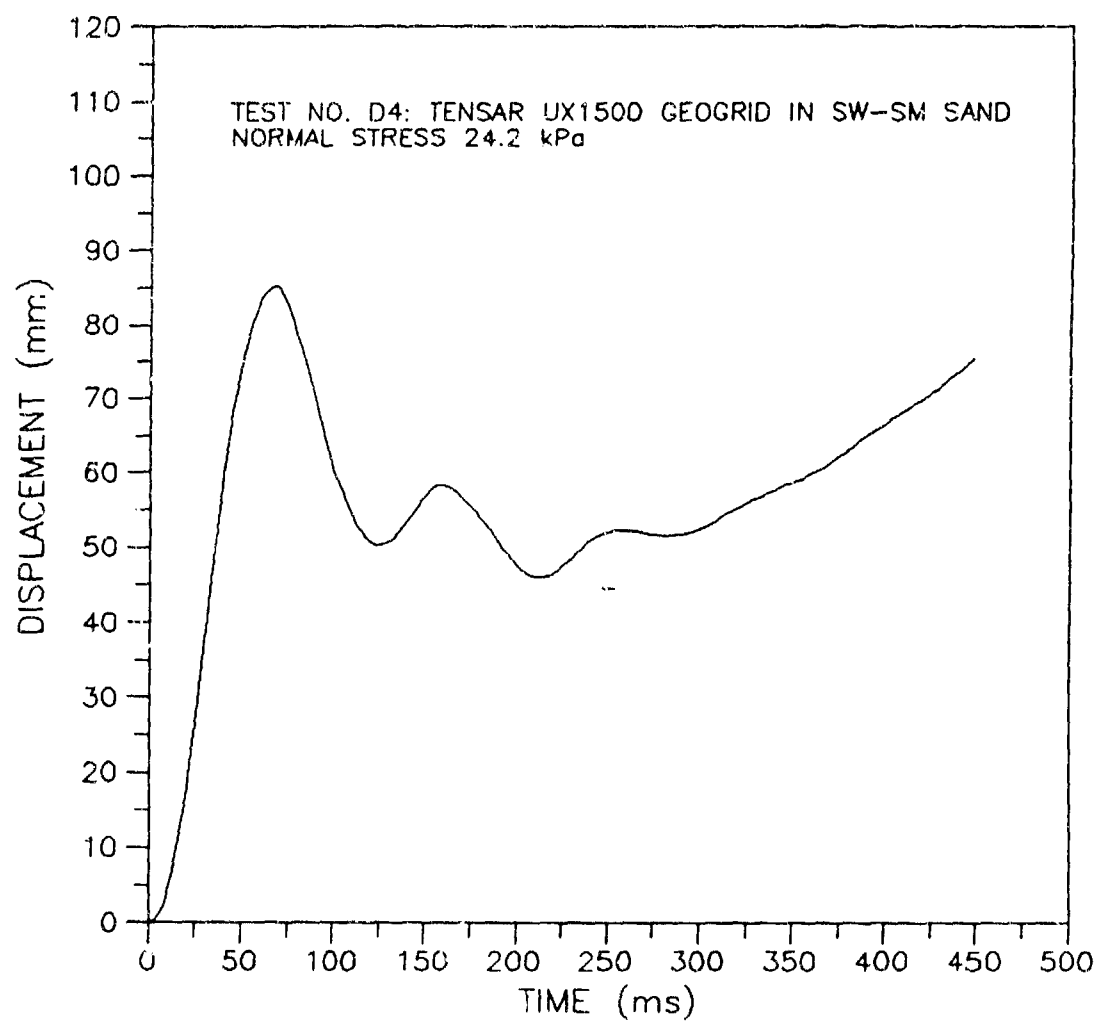
Figure 81.   Displacement Time History at Pulling End of Tensar UX1500
Geogrid for Test D4.

86
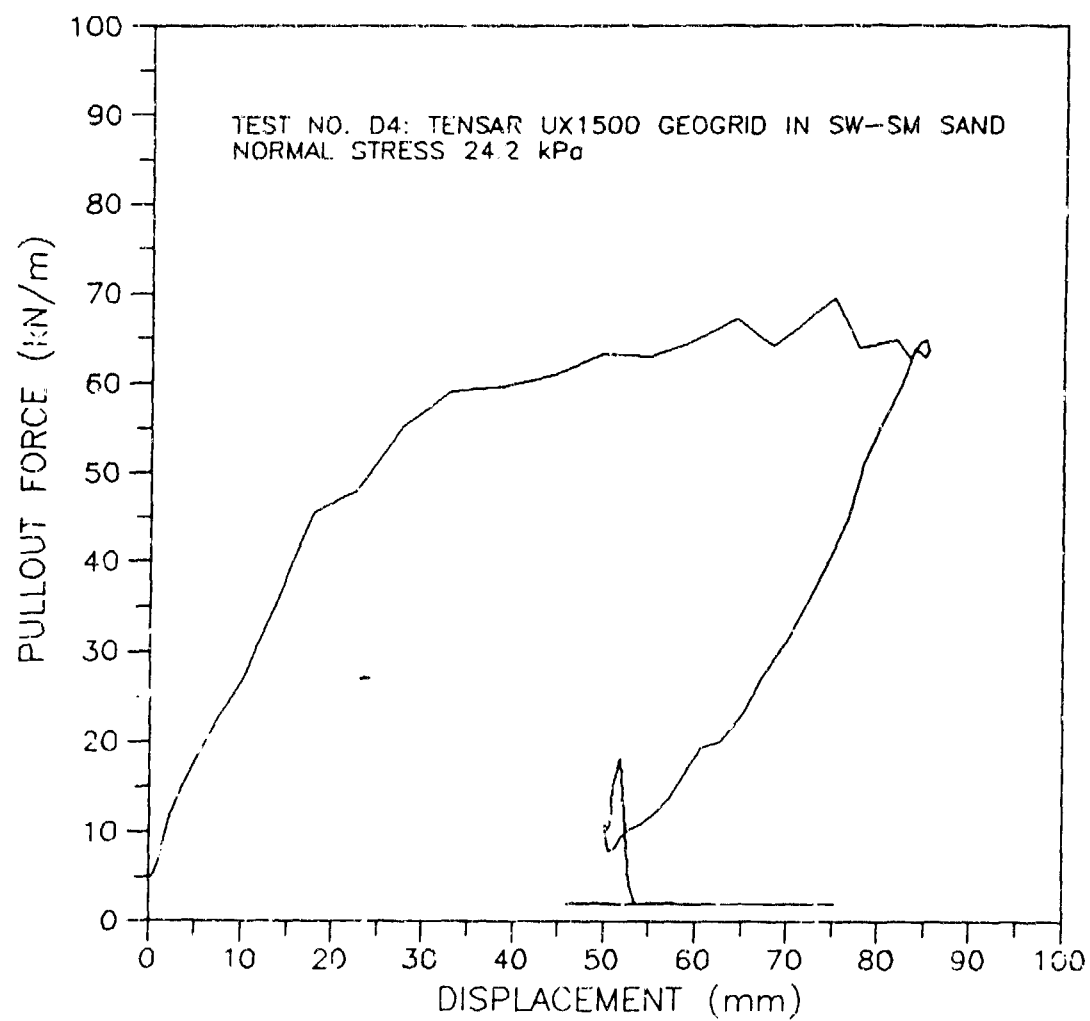
Figure 82.   Dynamic Pullout Response of Tensar UX1500 Geogrid
for Test D4.

87
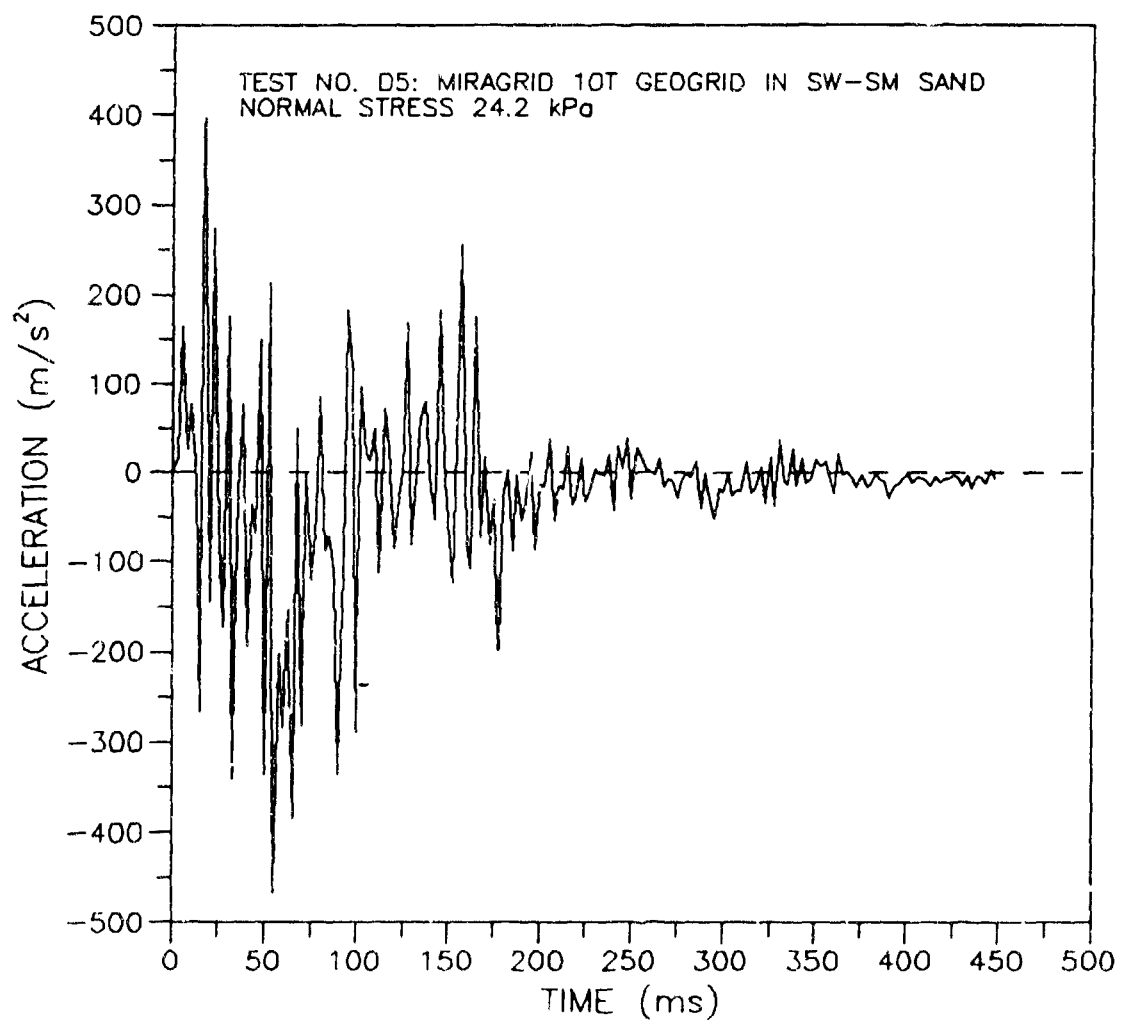
Figure 83. Measured Acceleration at Pulling End of M.ragrid 10T Geogrid for Test D5.
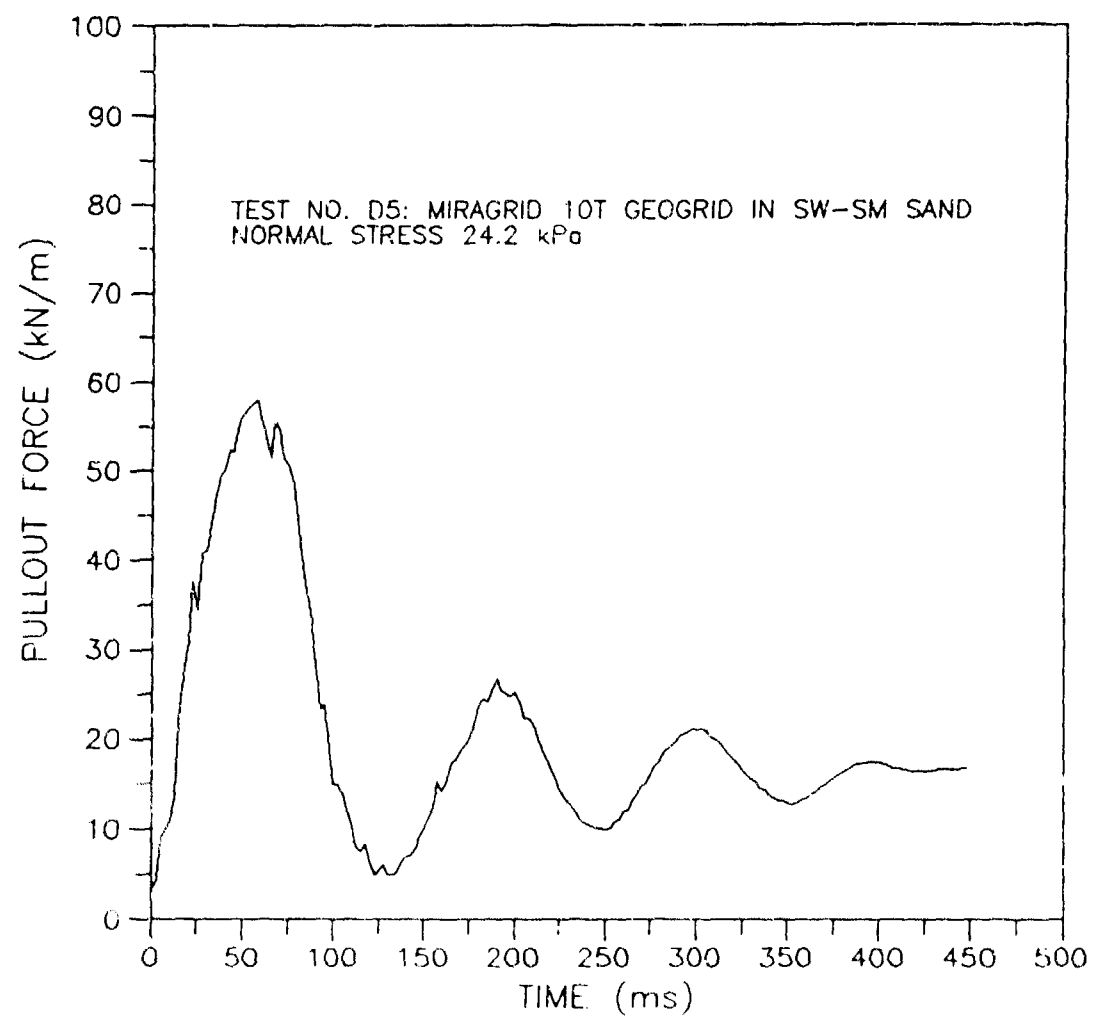
Figure 84. Measured Force at Pulling End of Miragrid 10T Geogrid for Test D5.

TEST NO. D5: MIRAGRID 10T GEOGRID IN SW-SM SAND
NORMAL STRESS 24.2 kPa
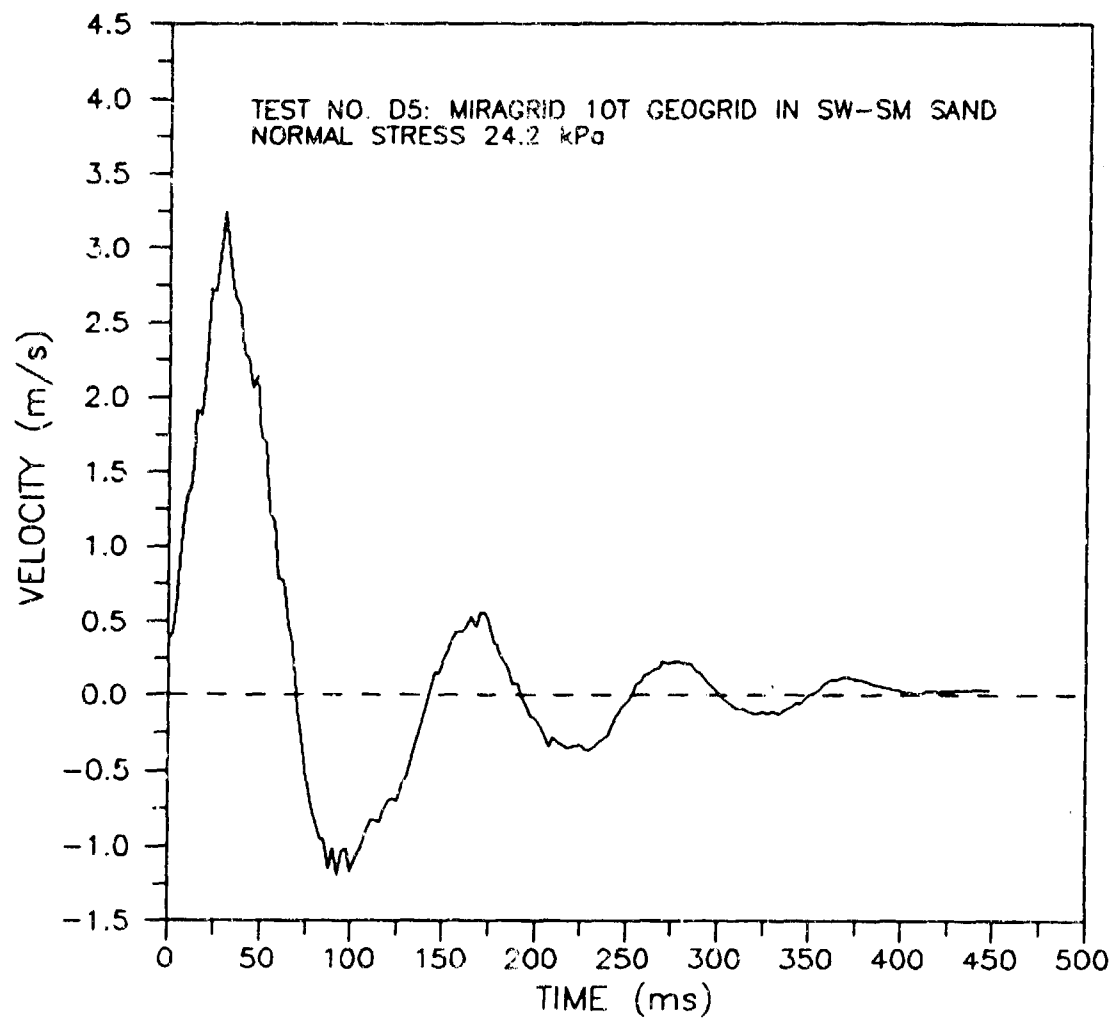
Figure 85.   Velocity Time History at Pulling End of Miragrid 10T
Geogrid for Test D5.

90
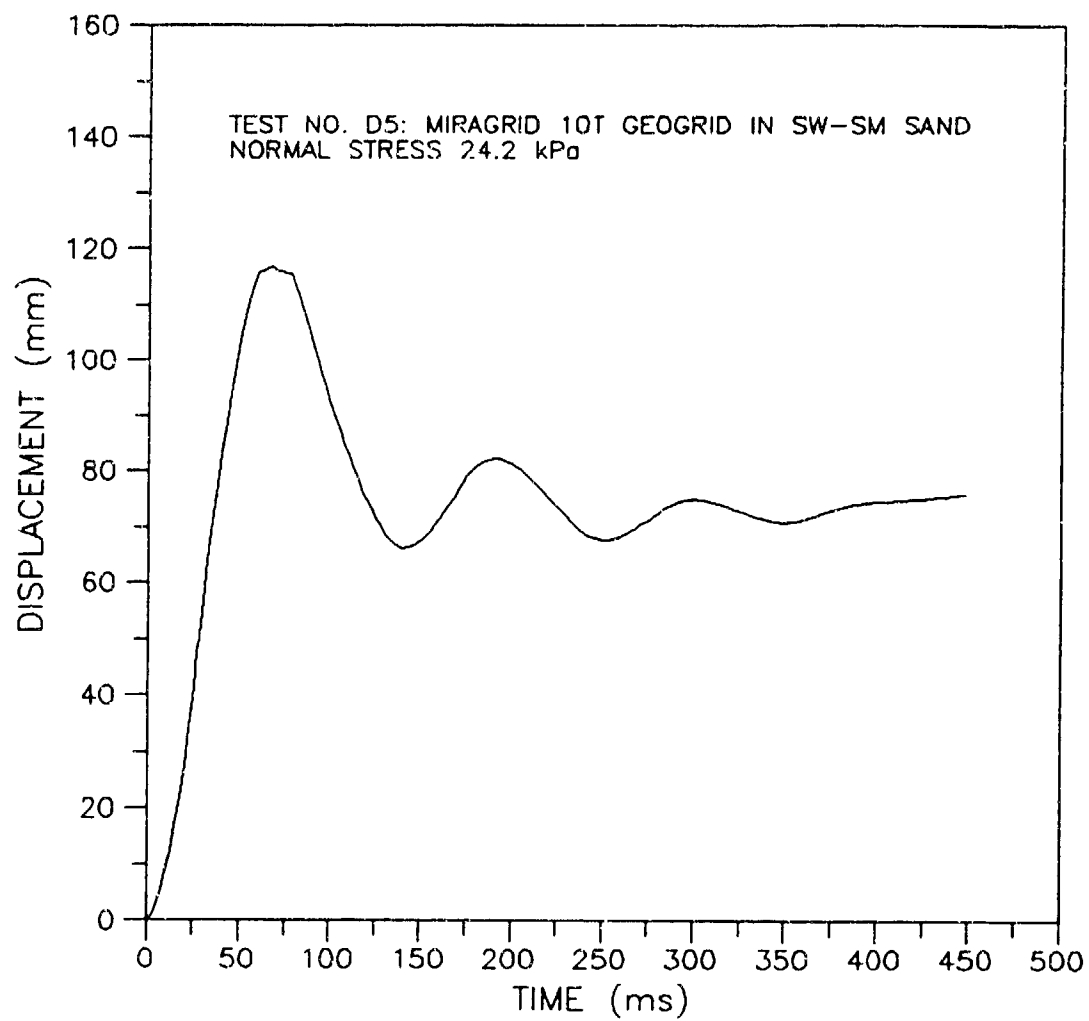
Figure 86.   Displacement Time History at Pulling End of Miragrid 10T
             Geogrid for Test D5.

91
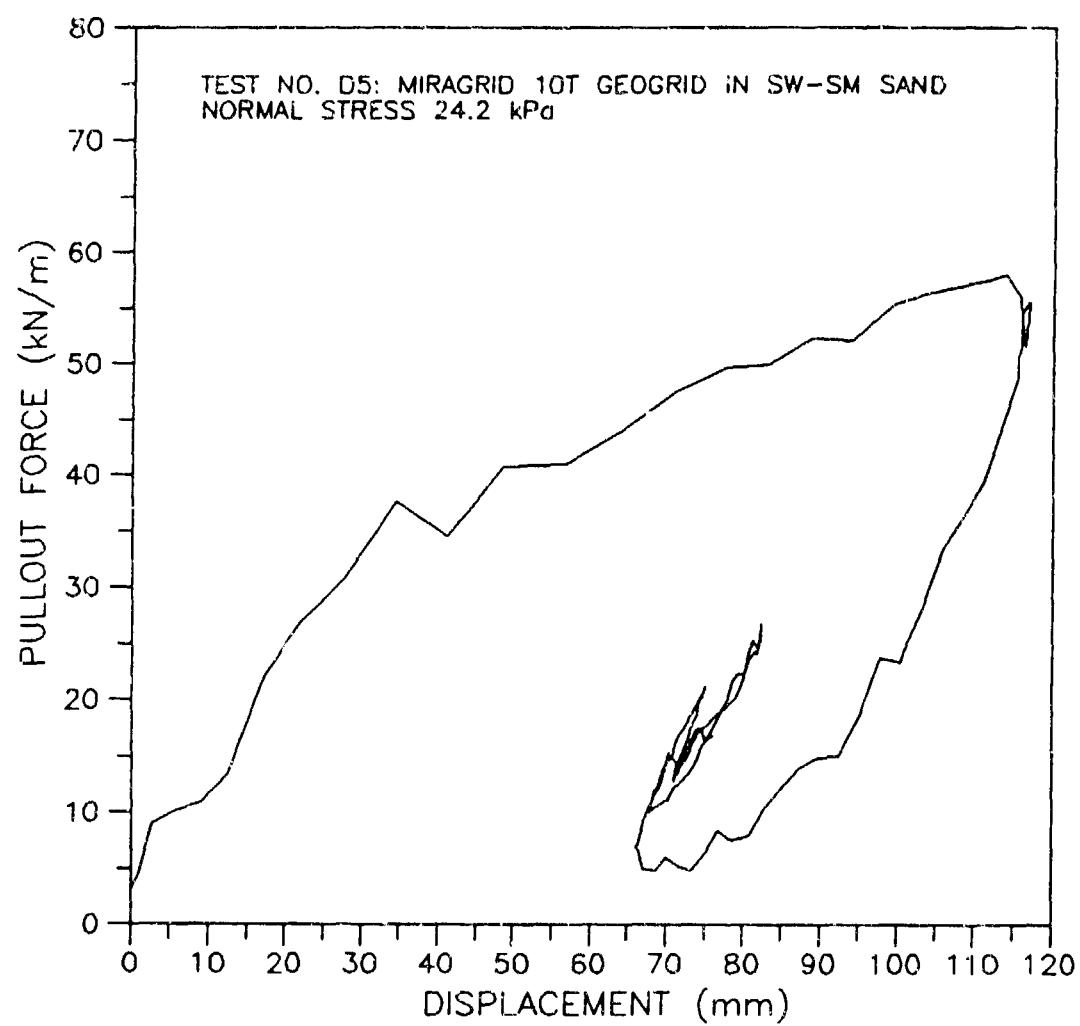
Figure 87. Dynamic Pullout Response of Miragrid 10T Geogrid
            for Test D5.

92
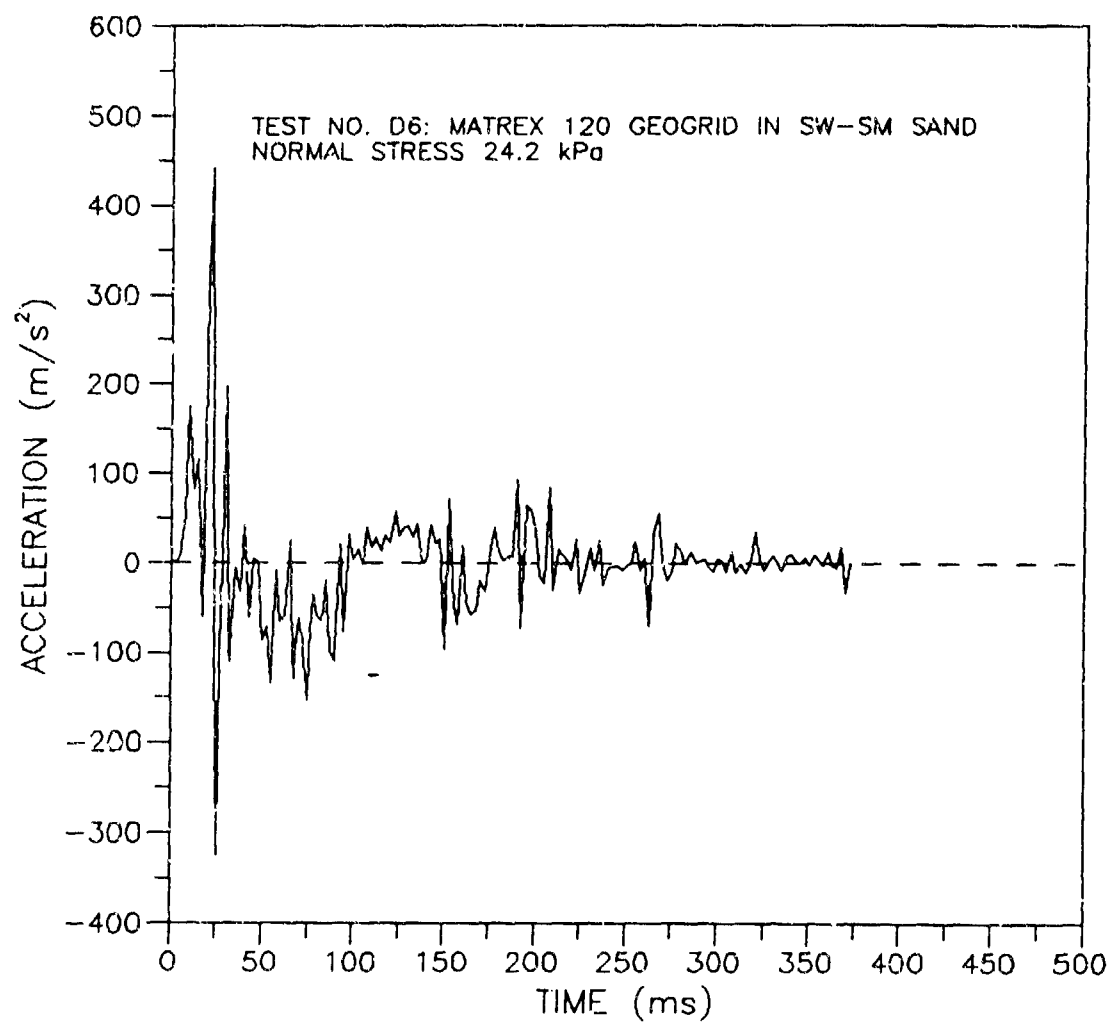
Figure 88.   Measured Acceleration at Pulling End of Matrex 120
Geogrid for Test D6.

93
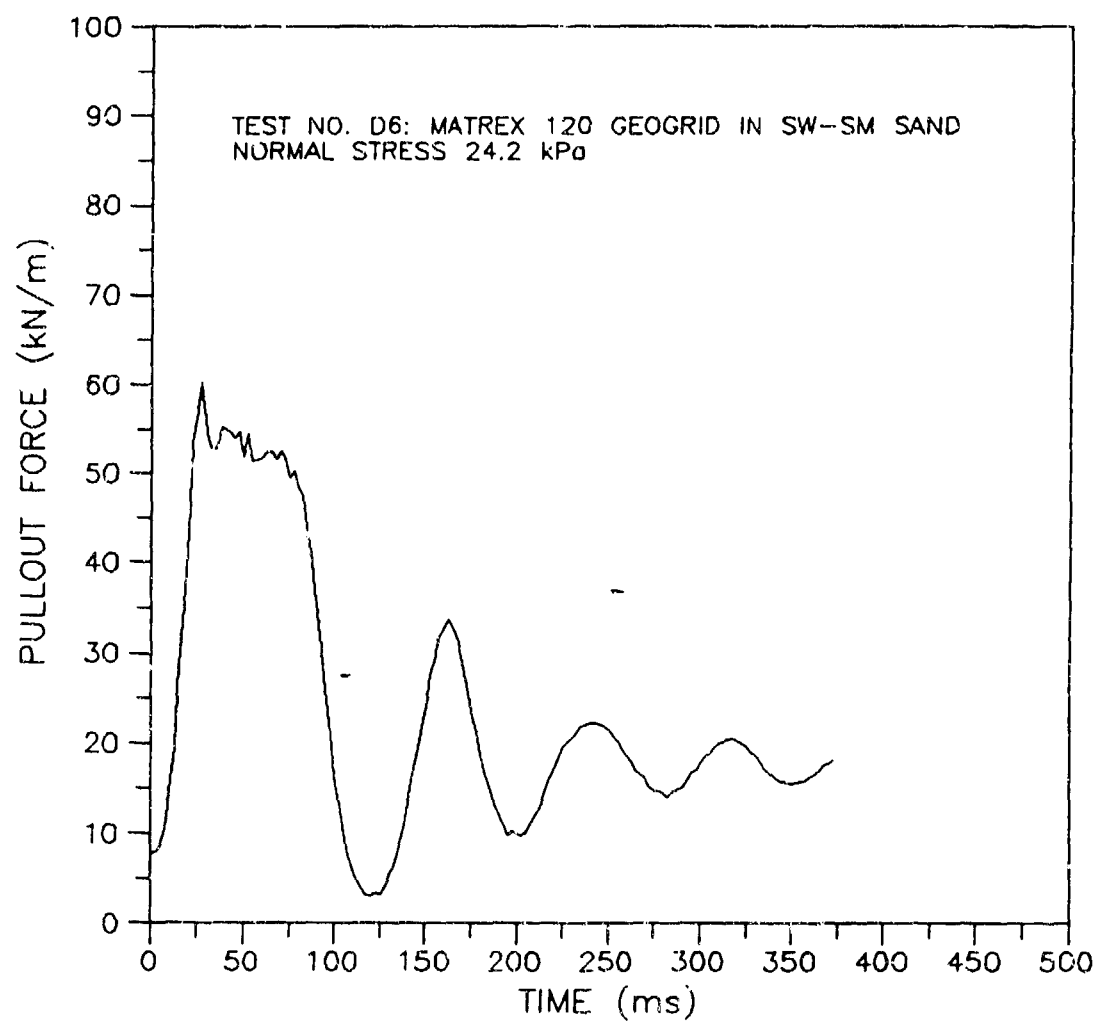
Figure 89.   Measured Force at Pulling End of Matrex 120 Geogrid
             for Test D6.

94
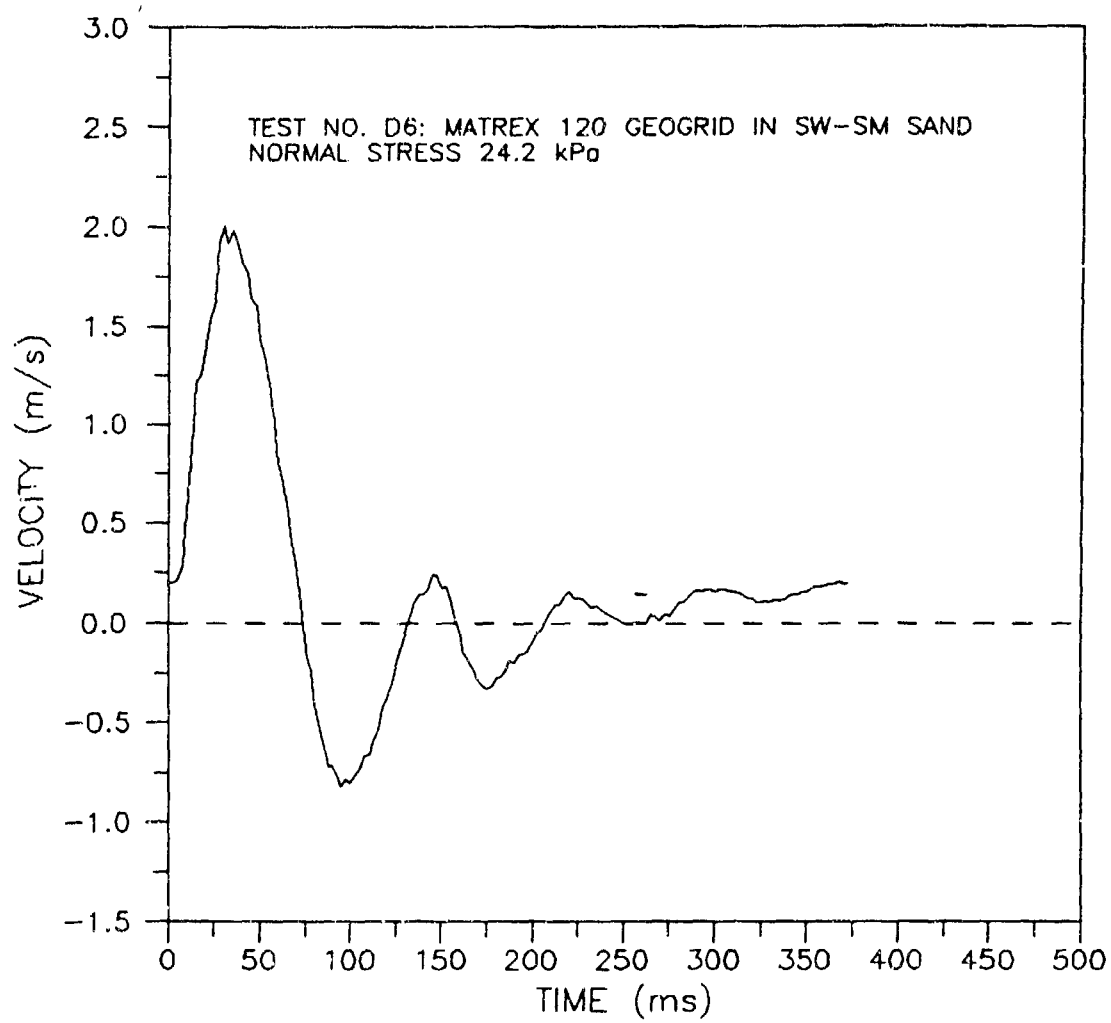
Figure 90.   Velocity Time History at Pulling End of Matrex 120
             Geogrid for Test D6.

95

TEST NO. D6: MATREX 120 GEOGRID IN SW--SM SAND
NORMAL STRESS 24.2 kPa
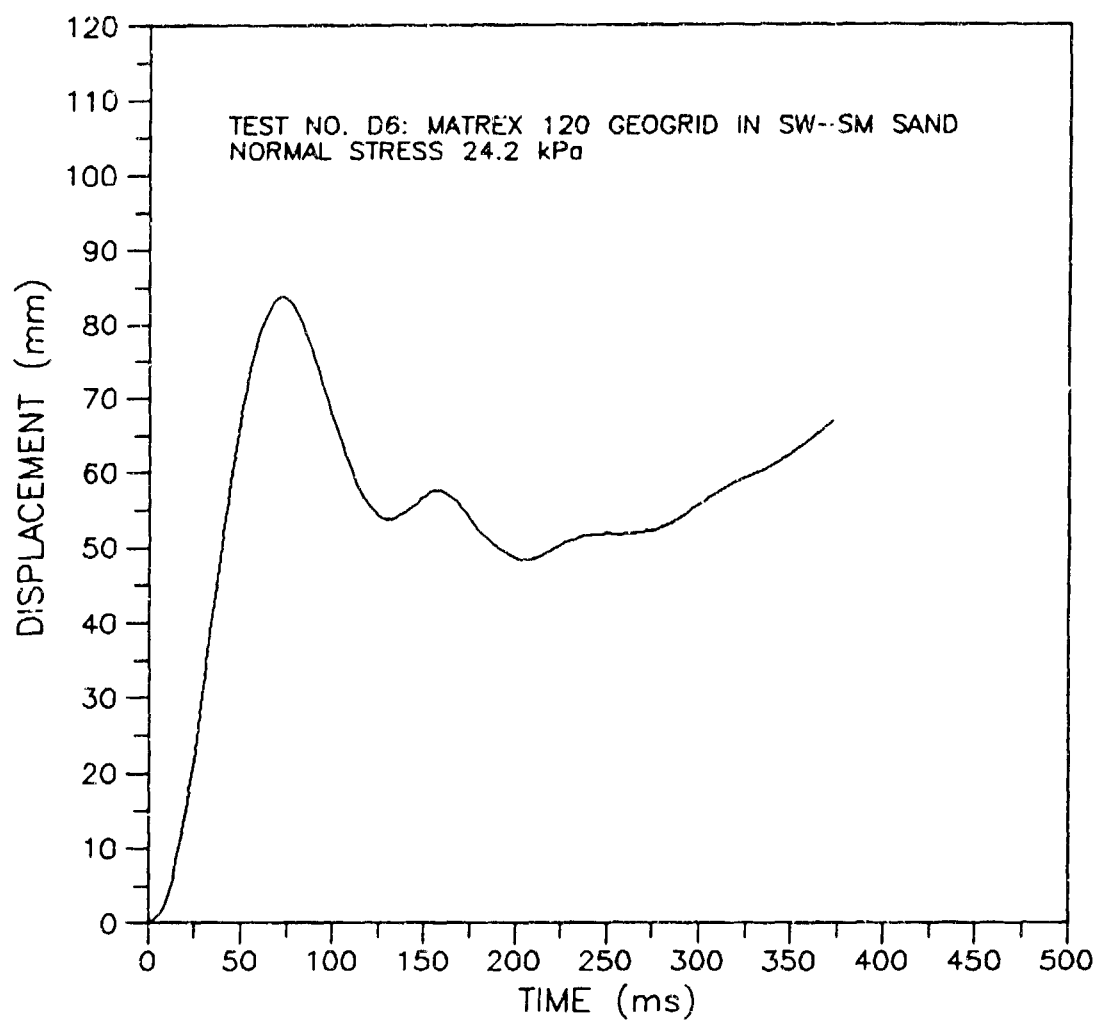
Figure 91.   Displacement Time History at Pulling End of Matrex 120
Geogrid for Test D6.

96
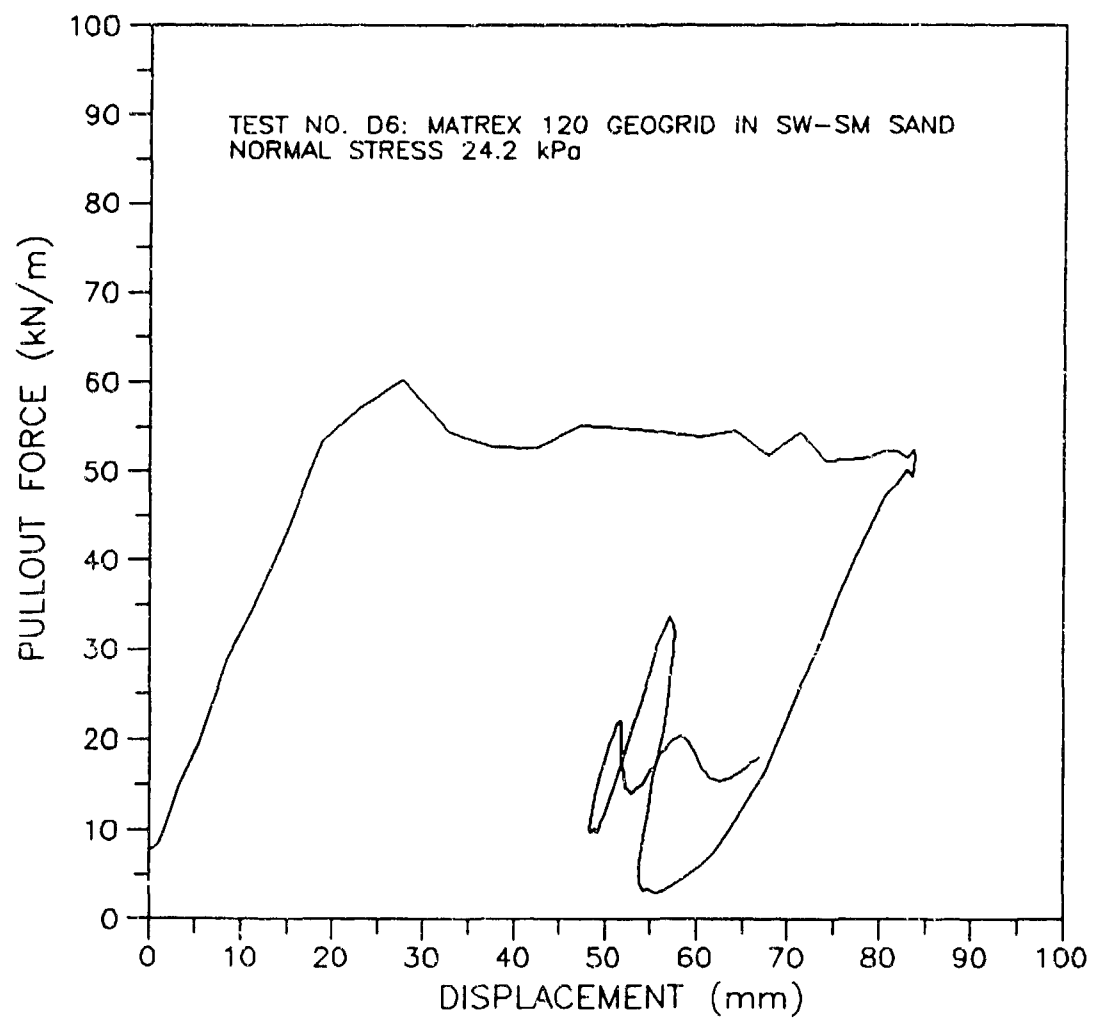
Figure 92.   Dynamic Pullout Response of Matrex 120 Geogrid
              for Test D6.

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APPENDIX B

NUMERICAL MODELING

A. INTRODUCTION

This appendix contains example input files for the computer codes INGRID (the pre-processor for DYNA3D) and DYNA3D, as well as figures showing deformed meshes from each analysis.

The example input file for INGRID, presented below in Part B, is annotated and contains the input data for the base analysis, PS1. The units used are meters, kilograms and seconds. The output file produced by INGRID is the DYNA3D input file presented in Section C. This file is also annotated with comments produced by INGRID and additional comments added by the authors. The portions of the DYNA3D input file needed for analysis PS1, but not produced by INGRID, are clearly marked out by comments. To reduce the length of the listing, only a few lines of node and element data are shown. Section D presents figures showing the deformed mesh shape at the end of each analysis described in Volume 1.

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B. EXAMPLE OF INGRID INPUT FILE

The following listing is an example of an INGRID input file. All lines beginning with a "c" are comments. Lower case letters are used for all INGRID input except comments. INGRID files should not begin with a comment; the first line listed below is the title to be used for the DYNA3D input file that INGRID will generate.

```
parametric study - base input file (plane strain)
c
c ... identify computer code for which data are being prepared
c
dn3d
c
c ... termination time for the DYNA analysis
c
term 0.03
c
c ...  time interval between writes of state plot data
c
plti 0.040
c
c ...  time interval between writes of time history plot data
c
prti 0.040                    -
c
c  .. gravity acceleration vector
c
grav 0. 0. 9.81
c
c ... for mass proportional damping add alpha=x directly into card 8 of
c      DYNA3D input file since INGRID can't generate rayleigh damping data.
c
c ... define type of sliding interface, static and dynamic friction coeff.
c      NOTE: the 10/17/89 version of INGRID will perform this
c      command correctly; the 6/27/91 version only puts the dynamic
c      friction coeff into the DYNA input file, the static coeff must be input
c      by hand
c
si 1   sv fric 0.9 kfric 0.9;
si 2   sv fric 0.9 kfric 0.9;
si 3   sv fric 0.9 kfric 0.9;
si 4   sv fric 0.9 kfric 0.9;
si 5   sv fric 0.9 kfric 0.9;
si 6   sv fric 0.9 kfric 0.9;
si 7   sv fric 0.9 kfric 0.9;
```

```
si 8   sv fric 0.9 kfric 0.9;
si 9   sv fric 0.9 kfric 0.9;
si 10  sv fric 0.9 kfric 0.9;
si 11  sv fric 0.9 kfric 0.9;
si 12  sv fric 0.9 kfric 0.9;
si 13     tied;
si 14  sv fric 1.5 kfric 1.5;
si 15  sv fric 1.5 kfric 1.5;
si 16  sv fric 1.5 kfric 1.5;
si 17  sv fric 1.5 kfric 1.5;
si 18  sv fric 1.5 kfric 1.5;
si 19     tied;
si 20     tied;
si 21     tied;
si 22     tied;
si 23     tied;
si 24     tied;
si 25  sv fric 0.7 kfric 0.7;
si 26  sv fric 0.7 kfric 0.7;
si 27  sv fric 0.7 kfric 0.7;
si 28  sv fric 0.7 kfric 0.7;
si 29  sv fric 0.7 kfric 0.7;
si 30  sv fric 0.7 kfric 0.7;
si 31  sv fric 0.0 kfric 0.0;
si 32  sv fric 1.5 kfric 1.5;
si 33  sv fric 1.5 kfric 1.5;
c
c ... define two planes of symmetry
c
plane 2   0. 0.0 0.    0. -1. 0.    0.005 symm
          0. 0.1 0.    0.  1. 0.    0.005 symm
c
c ... define gravity loading time history
c
lcd    1  5
0.0    0.0
0.02   0.1
0.06   0.9
0.08   1.0
10.00  1.0
c
c ... define velocity time history for blast simulation, one for each node
c
lcd    2 11
 0.000E+00   0.000E+00
 0.839E-01   0.000E+00
 0.849E-01   0.100E+01
 0.889E-01   0.886E+00
 0.939E-01   0.781E+00
 0.104E+00   0.599E+00
 0.134E+00   0.221E+00
 0.184E+00  -0.059E+00
 0.284E+00  -0.127E+00
 0.500E+00   0.000E+00
```

100

```
            0.200E+01   0.000E+00
     lcd   3 11
         0.000E+00   0.000E+00
         0.830E-01   0.000E+00
         0.839E-01   0.100E+01
         0.880E-01   0.874E+00
         0.930E-01   0.760E+00
         0.103E+00   0.564E+00
         0.133E+00   0.174E+00
         0.183E+00  -0.865E-01
         0.283E+00  -1.165E-01
         0.500E+00   0.000E+00
         0.200E+01   0.000E+00
     lcd   4 11
         0.000E+00   0.000E+00
         0.821E-01   0.000E+00
         0.829E-01   0.100E+01
         0.871E-01   0.860E+00
         0.921E-01   0.736E+00
         0.102E+00   0.525E+00
         0.132E+00   0.126E+00
         0.182E+00  -1.086E-01
         0.282E+00  -1.021E-01
         0.500E+00   0.000E+00
         0.200E+01   0.000E+00
     lcd   5 11
         0.000E+00   0.000E+00
         0.817E-01   0.000E+00
         0.824E-01   0.100E+01
         0.867E-01   0.853E+00
         0.917E-01   0.723E+00
         0.102E+00   0.505E+00
         0.132E+00   0.121E+00
         0.182E+00  -1.171E-01
         0.282E+00  -9.420E-02
         0.500E+00   0.000E+00
         0.200E+01   0.000E+00
     lcd   6 11
         0.000E+00   0.000E+00
         0.814E-01   0.000E+00
         0.821E-01   0.100E+01
         0.864E-01   0.848E+00
         0.914E-01   0.714E+00
         0.101E+00   0.491E+00
         0.131E+00   0.870E-01
         0.181E+00  -1.220E-01
         0.281E+00  -8.860E-02
         0.500E+00   0.000E+00
         0.200E+01   0.000E+00
     lcd   7 11
         0.000E+00   0.000E+00
         0.813E-01   0.000E+00
         0.820E-01   0.100E+01
         0.863E-01   0.846E+00
```

```
0.913E-01   0.710E+00
0.101E+00   0.484E+00
0.131E+00   0.798E-01
0.181E+00  -1.240E-01
0.281E+00  -8.600E-02
0.500E+00   0.000E+00
0.200E+01   0.000E+00
lcd   8 11
0.000E+00   0.000E+00
0.811E-01   0.000E+00
0.818E-01   0.100E+01
0.861E-01   0.843E+00
0.911E-01   0.704E+00
0.101E+00   0.476E+00
0.131E+00   0.707E-01
0.181E+00  -1.263E-01
0.281E+00  -8.260E-02
0.500E+00   0.000E+00
0.200E+01   0.000E+00
lcd   9 11
0.000E+00   0.000E+00
0.810E-01   0.000E+00
0.817E-01   0.100E+01
0.860E-01   0.840E+00
0.910E-01   0.700E+00
0.101E+00   0.470E+00
0.131E+00   0.640E-01
0.181E+00  -1.279E-01
0.281E+00  -8.010E-02
0.500E+00   0.000E+00
0.200E+01   0.000E+00
lcd   10 11
0.000E+00   0.000E+00
0.808E-01   0.000E+00
0.815E-01   0.100E+01
0.858E-01   0.836E+00
0.908E-01   0.692E+00
0.101E+00   0.457E+00
0.131E+00   0.507E-01
0.181E+00  -1.306E-01
0.281E+00  -7.490E-02
0.500E+00   0.000E+00
0.200E+01   0.000E+00
lcd   11 11
0.000E+00   0.000E+00
0.806E-01   0.000E+00
0.813E-01   0.100E+01
0.856E-01   0.831E+00
0.906E-01   0.683E+00
0.101E+00   0.444E+00
0.131E+00   0.386E-01
0.181E+00  -1.325E-01
0.281E+00  -7.020E-02
0.500E+00   0.000E+00
```

```
          0.200E+01   0.000E+00
   lcd  12 11
          0.000E+00   0.000E+00
          0.805E-01   0.000E+00
          0.812E-01   0.100E+01
          0.855E-01   0.829E+00
          0.905E-01   0.680E+00
          0.101E+00   0.439E+00
          0.131E+00   0.334E-01
          0.181E+00  -1.332E-01
          0.281E+00  -6.820E-02
          0.500E+00   0.000E+00
          0.200E+01   0.000E+00
   lcd  13 11
          0.000E+00   0.000E+00
          0.804E-01   0.000E+00
          0.810E-01   0.100E+01
          0.854E-01   0.826E+00
          0.904E-01   0.675E+00
          C.100E+00   0.432E+00
          0.130E+00   0.271E-01
          0.180E+00  -1.339E-01
          0.280E+00  -6.570E-02
          0.500E+00   0.000E+00
          0.200E+01   0.000E+00
   lcd  14 11
          0.000E+00   0.000E+00
          0.803E-01   0.000E+00
          0.810E-01   0.100E+01
          0.853E-01   0.824E+00
          0.903E-01   0.672E+00
          0.100E+00   0.428E+00
          0.130E+00   0.226E-01
          0.180E+00  -1.343E-01
          0.280E+00  -6.390E-02
          0.500E+00   0.000E+00
          0.200E+01   0.000E+00
   lcd  15 11
          0.000E+00   0.000E+00
          0.802E-01   0.000E+00
          0.808E-01   0.100E+01
          0.852E-01   0.821E+00
          0.902E-01   0.666E+00
          0.100E+00   0.419E+00
          0.130E+00   0.146E-01
          0.180E+00  -1.349E-01
          0.280E+00  -6.080E-02
          0.500E+00   0.000E+00
          0.200E+01   0.000E+00
   lcd  16 11
          0.000E+00   0.000E+00
          0.801E-01   0.000E+00
          0.807E-01   0.100E+01
          0.851E-01   0.818E+00
```

```
      0.901E-01   0.662E+00
      0.100E+00   0.412E+00
      0.130E+00   0.840E-02
      0.180E+00  -1.352E-01
      0.280E+00  -5.830E-02
      0.500E+00   0.000E+00
      0.200E+01   0.000E+00
 lcd   17 11
      0.000E+00   0.000E+00
      0.801E-01   0.000E+00
      0.807E-01   0.100E+01
      0.851E-01   0.817E+00
      0.901E-01   0.660E+00
      0.100E+00   0.409E+00
      0.130E+00   0.620E-02
      0.180E+00  -1.353E-01
      0.280E+00  -5.740E-02
      0.500E+00   0.000E+00
      0.200E+01   0.000E+00
 lcd   18 11
      0.000E+00   0.000E+00
      0.800E-01   0.000E+00
      0.806E-01   0.100E+01
      0.850E-01   0.816E+00
      0.900E-01   0.658E+00
      0.100E+00   0.407E+00
      0.130E+00   0.390E-02
      0.180E+00  -1.353E-01
      0.280E+00  -5.650E-02
      0.500E+00   0.000E+00
      0.200E+01   0.000E+00
 lcd   19 11
      0.000E+00   0.000E+00
      0.800E-01   0.000E+00
      0.806E-01   0.100E+01
      0.850E-01   0.816E+00
      0.900E-01   0.657E+00
      0.100E+00   0.405E+00
      0.130E+00   0.270E-02
      0.180E+00  -1.353E-01
      0.280E+00  -5.600E-02
      0.500E+00   0.000E+00
      0.200E+01   0.000E+00
 lcd   20 11
      0.000E+00   0.000E+00
      0.800E-01   0.000E+00
      0.806E-01   0.100E+01
      0.850E-01   0.815E+00
      0.900E-01   0.656E+00
      0.100E+00   0.404E+00
      0.130E+00   0.160E-02
      0.180E+00  -1.353E-01
      0.280E+00  -5.560E-02
      0.500E+00   0.000E+00
```

```
0.200E+01   0.000E+00
lcd   21 11
0.000E+00   0.000E+00
0.800E-01   0.000E+00
0.806E-01   0.100E+01
0.850E-01   0.816E+00
0.900E-01   0.657E+00
0.100E+00   0.405E+00
0.130E+00   0.270E-02
0.180E+00  -1.353E-01
0.280E+00  -5.600E-02
0.500E+00   0.000E+00
0.200E+01   0.000E+00
lcd   22 11
0.000E+00   0.000E+00
0.800E-01   0.000E+00
0.806E-01   0.100E+01
0.850E-01   0.816E+00
0.900E-01   0.658E+00
0.100E+00   0.407E+00
0.130E+00   0.390E-02
0.180E+00  -1.353E-01
0.280E+00  -5.550E-02
0.500E+00   0.000E+00
0.200E+01   0.000E+00
lcd   23 11
0.000E+00   0.000E+00
0.801E-01   0.000E+00
0.807E-01   0.100E+01
0.851E-01   0.817E+00
0.901E-01   0.660E+00
C.100E+00   0.409E+00
0.130E+00   0.620E-02
0.180E+00  -1.353E-01
0.280E+00  -5.740E-02
0.500E+00   0.000E+00
0.200E+01   0.000E+00
lcd   24 11
0.000E+00   0.000E+00
0.801E-01   0.000E+00
0.807E-01   0.100E+01
0.851E-01   0.818E+00
0.901E-01   0.662E+00
0.100E+00   0.412E+00
0.130E+00   0.840E-02
0.180E+00  -1.352E-01
0.280E+00  -5.830E-02
0.500E+00   0.000E+00
0.200E+01   0.000E+00
lcd   25 11
0.000E+00   C.000E+00
0.802E-01   0.000E+00
0.808E-01   0.100E+01
0.852E-01   0.821E+00
```

105

```
0.902E-01   0 666E+00
0.100E+00   0.419E+00
0.130E+00   0.146E-01
0.180E+00  -1.349E-01
0.280E+00  -6.080E-02
0.500E+00   0.000E+00
0.200E+01   0.000E+00
lcd   26 11
0.000E+00   0.000E+00
0.803E-01   0.000E+00
0.810E-01   0.100E+01
0.853E-01   0.824E+00
0.903E-01   0.672E+00
0.100E+00   0.428E+00
0.130E+00   0.226E-01
0.180E+00  -1.343E-01
0.280E+00  -6.390E-02
0.500E+00   0.000E+00
0.200E+01   0.000E+00
lcd   27 11
0.000E+00   0.000E+00
0.804E-01   0.000E+00
0.810E-01   0.100E+01
0.854E-01   0.826E+00
0.904E-01   0.675E+00
0.100E+00   0.432E+00
0.130E+00   0.271E-01
0.180E+00  -1.339E-01
0.280E+00  -6.570E-02
0.500E+00   0.000E+00
0.200E+01   0.000E+00
lcd   28 11
0.000E+00   0.000E+00
0.805E-01   0.000E+00
0.812E-01   0.100E+01
0.855E-01   0.829E+00
0.905E-01   0.680E+00
0.101E+00   0.439E+00
0.131E+00   0.334E-01
0.181E+00  -1.332E-01
0.281E+00  -6.820E-02
0.500E+00   0.000E+00
0.200E+01   0.000E+00
lcd   29 11
0.000E+00   0.000E+00
0.806E-01   0.000E+00
0.813E-01   0.100E+01
0.856E-01   0.831E+00
0.906E-01   0.683E+00
0.101E+00   0.444E+00
0.131E+00   0.386E-01
0.181E+00  -1.325E-01
0.281E+00   7.020E-02
0.500E+00   0.000E+00
```

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```
    0.200E+01   0.000E+00
lcd   30 11
    0.000E+00   0.000E+00
    0.808E-01   0.000E+00
    0.815E-01   0.100E+01
    0.858E-01   0.836E+00
    0.908E-01   0.692E+00
    0.101E+00   0.457E+00
    0.131E+00   0.507E-01
    0.181E+00  -1.306E-01
    0.281E+00  -7.490E-02
    0.500E+00   0.000E+00
    0.200E+01   0.000E+00
lcd   31 11
    0.000E+00   0.000E+00
    0.810E-01   0.000E+00
    0.817E-01   0.100E+01
    0.860E-01   0.840E+00
    0.910E-01   0.700E+00
    0.101E+00   0.470E+00
    0.131E+00   0.640E-01
    0.181E+00  -1.279E-01
    0.281E+00  -8.010E-02
    0.500E+00   0.000E+00
    0.200E+01   0.000E+00
lcd   32 11
    0.000E+00   0.000E+00
    0.811E-01   0.000E+00
    0.818E-01   0.100E+01
    0.861E-01   0.843E+00
    0.911E-01   0.704E+00
    0.101E+00   0.476E+00
    0.131E+00   0.707E-01
    0.181E+00  -1.263E-01
    0.281E+00  -8.260E-02
    0.500E+00   0.000E+00
    0.200E+01   0.000E+00
lcd   33 11
    0.000E+00   0.000E+00
    0.813E-01   0.000E+00
    0.820E-01   0.100E+01
    0.863E-01   0.816E+00
    0.913E-01   0.710E+00
    0.101E+00   0.484E+00
    0.131E+00   0.793E-01
    0.181E+00  -1.240E-01
    0.281E+00  -8.600E-02
    0.500E+00   0.000E+00
    0.200E+01   0.000E+00
lcd   34 11
    0.000E+00   0.000E+00
    0.814E-01   0.000E+00
    0.821E-01   0.100E+01
    0.864E-01   0.848E+00
```

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```
 0.914E-01  0.714E+00
 0.101E+00  0.491E+00
 0.131E+00  0.870E-01
 0.181E+00 -1.220E-01
 0.282E+00 -8.860E-02
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
lcd  35 11
 0.000E+00  0.000E+00
 0.817E-01  0.000E+00
 0.824E-01  0.100E+01
 0.867E-01  0.853E+00
 0.917E-01  0.723E+00
 0.102E+00  0.505E+00
 0.132E+00  0.121E+00
 0.182E+00 -1.171E-01
 0.282E+00 -9.420E-02
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
c
c   .. Information for part 1
c
start
c
c ... Define index space for base soil
c
1  10 11 12 27; 1 2; 1 2 3 4 5;
0. 2.7 2.85 3.0 7.5
0. 0.10
0. 0.6 1.2 1.80 2.10                    --
c
c ... define boundary conditions on bottom
c
b  1 1 1    5 2 1    101000
c
c ... place nonreflecting boundary at left hand side
c
nri -1; 1 2; 1 5;
c
c ... define master surface between base and bottom facing element
c
sii- 1 5; 1 2; -5; 32 m 8. 0. 0.
c
c ... define material used in part 1
c
mate 1
c
c ... end definition of part 1
c
end
c
c ... Information for part 2
c
start
```

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```
c
c ... define index space for reinforced soil above and below reinforcement
c
1 16; 1 2; 1 2 3 4 0 6 7 8 9 10 11 12 0 14 15 16 17 18 19 20 0
22 23 24 25 26 27 28 0 30 31 32 33 34 35 36 0 38 39 40 41 42 43 44 0 46
47 48 49;
3.0 7.5
0. 0.1
2.10    2.31    2.41    2.4625 2.4625 2.4875 2.54    2.64    2.85    3.06
3.16    3.2125 3.2125 3.2375 3.29    3.39    3.6     3.81    3.91    3.9625
3.9625 3.9875 4.04    4.14    4.35    4.56    4.66    4.7125 4.7125 4.7375
4.79    4.89    5.1     5.31    5.41    5.4625 5.4625 5.4875 5.54    5.64 5.85
6.06    6.16    6.2125 6.2125 6.2375 6.29    6.39    6.6
c
c ... define slave surface for sliding between soil and wall
c
sii- -1; 1 2; 1 9; 25 s 8. 0.05 4.
sii- -1; 1 2; 9 17; 26 s 8. 0.05 4.
sii- -1; 1 2; 17 25; 27 s 8. 0.05 4.
sii- -1; 1 2; 25 33; 28 s 8. 0.05 4.
sii- -1; 1 2; 33 41; 29 s 8. 0.05 4.
sii- -1; 1 2; 41 49; 30 s 8. 0.05 4.
c
c ... define master surface  between soil and reinforcement
c
sii- 1 2; 1 2;   -4;  1 m 5. 0.05 0.
sii- 1 2; 1 2;   -6;  2 m 5. 0.05 10.
sii- 1 2; 1 2;  -12;  3 m 5. 0.05 0.
sii- 1 2; 1 2;  -14;  4 m 5. 0.05 10.
sii- 1 2; 1 2;  -20;  5 m 5. 0.05 0.
sii- 1 2; 1 2;  -22;  6 m 5. 0.05 10.
sii- 1 2; 1 2;  -28;  7 m 5. 0.05 0.
sii- 1 2; 1 2;  -30;  8 m 5. 0.05 10
sii- 1 2; 1 2;  -36;  9 m 5. 0.05 0.
sii- 1 2; 1 2;  -38; 10 m 5. 0.05 10.
sii- 1 2; 1 2;  -44; 11 m 5. 0.05 0.
sii- 1 2; 1 2;  -46; 12 m 5. 0.05 10.
c
c define slave interface tied with soil to right
c
sii+ -2; 1 2; 1 49; 13 s 10. 0.05 4.
c
c ... define sliding interface with roof
c
sii- 1 2; 1 2; -49; 33 s 5. 0.05 0.
c
c ... define material used in part 2
c
mate 1
c
c ... end definition of part 2
c
end
c
```

```
c ... Information for part 3
c
start
c
c ... define index space for reinforcement
c
1 31; 1 2; 1 4 0 6 9 0 11 14 0 16 19 0 21 24 0 26 29;
3.0 7.5
0. 0.1
2.4625 2.4875 2.4875 3.2125 3.2375 3.2375 3.9625 3.9875 3.9875
4.7125 4.7375 4.7375 5.4625 5.4875 5.4875 6.2125 6.2375
c
c ... define slave surface between reinforcement and soil
c
sii- 1 2; 1 2;  -1;  1 s 5. 0.05 10.
sii- 1 2; 1 2;  -2;  2 s 5. 0.05 0.
sii- 1 2; 1 2;  -4;  3 s 5. 0.05 10.
sii- 1 2; 1 2;  -5;  4 s 5. 0.05 0.
sii- 1 2; 1 2;  -7;  5 s 5. 0.05 10.
sii- 1 2; 1 2;  -8;  6 s 5. 0.05 0.
sii- 1 2; 1 2; -10;  7 s 5. 0.05 10.
sii- 1 2; 1 2; -11;  8 s 5. 0.05 0
sii- 1 2; 1 2; -13;  9 s 5. 0.05 10.
sii- 1 2; 1 2; -14; 10 s 5. 0.05 0.
sii- 1 2; 1 2; -16; 11 s 5. 0.05 10.
sii- 1 2; 1 2; -17; 12 s 5. 0.05 0.
c
c ... define slave surface tied between reinforcement and wall
c
sii+ -1; 1 2;  1  2; 19 s 0. 0.05 4.
sii+ -1; 1 2;  4  5; 20 s 0. 0.05 4.
sii+ -1; 1 2;  7  8; 21 s 0. 0.05 4.
sii+ -1; 1 2; 10 11; 22 s 0. 0.05 4.
sii+ -1; 1 2; 13 14; 23 s 0. 0.05 4.
sii+ -1; 1 2; 16 17; 24 s 0. 0.05 4.
c
c ... define material used in part 3
c
mate 2
c
c ... end definition of part 3
c
end
c
c ... Information for part 4
c
start
c
c ... define index space for soil to right of reinforcment
c
1 6; 1 2; 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35;
7.5  8.0
0.  0.1
```

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```
       0. 0.6  1.2  1.80 2.10 2.31 2.41 2.54 2.64 2.85 3.06 3.16
       3.29 3.39 3.60 3.81 3.91 4.04 4.14 4.35 4.56 4.66 4.79 4.89
       5.10 5.31 5.41 5.54 5.64 5.85 6.06 6.16 6.29 6.39 6.6
       c
       c ... define boundary condition at bottom
       c
       b 1 1 1   2 2 1    101000
       c
       c ... define master surfaces with soil to left
       c
       sii+ -1; 1 2; 5 35; 13 m 0. 0.05 4.
       c
       c ... define slave surface with rigid body to right
       c
       sii- -2; 1 2; 1 35; 31 s 0. 0. 4.
       c
       c ... define velocity loading
       c
       fv  2 1 2      2 2 2      2    2.270e+00   -1.00   0.00 0.
       fv  2 1 3      2 2 3      3    3.226e+00   -1.00   0.00 0.
       fv  2 1 4      2 2 4      4    4.591e+00   -1.00   0.00 0.
       fv  2 1 5      2 2 5      5    5.453e+00   -1.00   0.00 0.
       fv  2 1 6      2 2 6      6    6.128e+00   -1.00   0.00 0.
       fv  2 1 7      2 2 7      7    6.468e+00   -1.00   0.00 0.
       fv  2 1 8      2 2 8      8    6.927e+00   -1.00   0.00 0.
       fv  2 1 9      2 2 9      9    7.290e+00   -1.00   0.00 0.
       fv  2 1 10     2 2 10     10   8.075e+00   -1.00   0.00 0.
       fv  2 1 11     2 2 11     11   8.869e+00   -1.00   0.00 0.
       fv  2 1 12     2 2 12     12   9.242e+00   -1.00   0.00 0.
       fv  2 1 13     2 2 13     13   9.715e+00   -1.00   0.00 0.
       fv  2 1 14     2 2 14     14   1.006e+01   -1.00   0.00 0.
       fv  2 1 15     2 2 15     15   1.073e+01   -1.00   0.00 0.
       fv  2 1 16     2 2 16     16   1.129e+01   -1.00   0.00 0.
       fv  2 1 17     2 2 17     17   1.150e+01   -1.00   0.00 0.
       fv  2 1 18     2 2 18     18   1.171e+01   -1.00   0.00 0.
       fv  2 1 19     2 2 19     19   1.183e+01   -1.00   0.00 0.
       fv  2 1 20     2 2 20     20   1.193e+01   -1.00   0.00 0.
       fv  2 1 21     2 2 21     21   1.183e+01   -1.00   0.00 0.
       fv  2 1 22     2 2 22     22   1.171e+01   -1.00   0.00 0.
       fv  2 1 23     2 2 23     23   1.150e+01   -1.00   0.00 0.
       fv  2 1 24     2 2 24     24   1.129e+01   -1.00   0.00 0.
       fv  2 1 25     2 2 25     25   1.073e+01   -1.00   0.00 0.
       fv  2 1 26     2 2 26     26   1.006e+01   -1.00   0.00 0.
       fv  2 1 27     2 2 27     27   9.715e+00   -1.00   0.00 0.
       fv  2 1 28     2 2 28     28   9.242e+00   -1.00   0.00 0.
       fv  2 1 29     2 2 29     29   8.869e+00   -1.00   0.00 0.
       fv  2 1 30     2 2 30     30   8.075e+00   -1.00   0.00 0.
       fv  2 1 31     2 2 31     31   7.290e+00   -1.00   0.00 0.
       fv  2 1 32     2 2 32     32   6.927e+00   -1.00   0.00 0.
       fv  2 1 33     2 2 33     33   6.468e+00   -1.00   0.00 0.
       fv  2 1 34     2 2 34     34   6.128e+00   -1.00   0.00 0.
       fv  2 1 35     2 2 35     35   5.453e+00   -1.00   0.00 0.
       c
       c ... define material used for part 4
```

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```
c
mate 1
c
c ... end definition of part 4
c
end
c
c ... Information for part 5a
c
start
c
c define index space for concrete facing - bottom element (block)
c
1 3; 1 2; 1 4;
2.85 3.0
0. 0.1
2.10 2.85
c
c ... define slave surface under concrete wall
c
sii- 1 2; 1 2; -1; 1 s 3. 0.05 10.
c
c define master surface at top of element
c
sii- 1 2; 1 2; -2; 14 m 3. 0.05 0.
c
c ... define master surface with reinforcement
c
sii+ -2; 1 2; 1 2; 19 m 10. 0.05 4.
c
c ... define slave surface under concrete wall
c
sii- 1 2; 1 2; -1; 32 s 3. 0-05 10.
c
c ... define master surface between wall and soil elements
c
sii- -2; 1 2; 1 2; 25 m 0. 0.05 4.
c
c ... define material used for part 5a
c
mate 3
c
c ... end definition of part 5a
c
end
c
c ... Information for part 5b
c
start
c
c ... define index space for concrete facing - bottom element + 1
c
1 3; 1 2; 1 4;
2.85 3.0
```

```
0. 0.1
2.85 3.60
c
c ... define slave surface at bottom of element
c
sii- 1 2; 1 2; -1; 14 s 3. 0.05 10.
c
c ... define master surface at top of element
c
sii- 1 2; 1 2; -2; 15 m 3. 0.05 0.
c
c ... define master surface with reinforcement
c
sii+ -2; 1 2; 1 2; 20 m 10. 0.05 4.
c
c ... define master surface between wall and soil elements
c
sii- -2; 1 2; 1 2; 26 m 0. 0.05 4.
c
c ... define material used for part 5b
c
mate 3
c
c ... end definition of part 5b
c
end
c
c ... Information for part 5c
c
start                               -
c
c define index space for concrete facing - bottom element ÷ 2
c
1 3; 1 2; 1 4:
2.85 3.0
0. 0.1
3.60 4.35
c
c ... define slave surface at bottom of element
c
sii- 1 2; 1 2; -1; 15 s 3. 0.05 10.
c
c ... define master surface at top of element
c
sii- 1 2; 1 2; -2; 16 m 3. 0.05 0.
c
c ... define master surface with reinforcement
c
sii+ -2; 1 2; 1 2; 21 m 10. 0.05 4.
c
c ... define master surface between wall and soil elements
c
sii- -2; 1 2; 1 2; 27 m 0. 0.05 4.
c
```

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```
c ... define material used for part 5c
c
mate 3
c
c ... end definition of part 5c
c
erd
c
c ... Information fcr part 5d
c
start
c
c ... define index space for concrete facing - bottom element + 3
c
1 3; 1 2; 1 4:
2.85 3.0
0. 0.1
4.35 5.10
c
c ... define slave surface at bottom of element
c
sii- 1 2; 1 2; -1; 16 s 3. 0.05 10.
c
c ... define master surface at top of element
c
sii- 1 2; 1 2; -2; 17 m 3. 0.05 0.
c
c ... define master surface with reinforcement
c
sii+ -2; 1 2; 1 2; 22 m 10. 0.05 4.          -
c
c ... define master surface between wall and soil elements
c
sii- -2; 1 2; 1 2; 28 m 0. 0.05 4.
c
c ... define material used for part 5d
c
mate 3
c
c ... end definition of part 5d
c
end
c
c ... Information fcr part 5e
c
start
c
c ... define index space for concrete facing - bottom element + 4
c
1 3; 1 2; 1 4:
2.85 3.0
0. 0.1
5.10 5.85
c
```

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```
c ... define slave surface at bottom of element
c
sii- 1 2; 1 2; -1; 17 s 3. 0.05 10.
c
c ... define master surface at top of element
c
sii- 1 2; 1 2; -2; 18 m 3. 0.05 0.
c
c ... define master surface with reinforcement
c
sii+ -2; 1 2; 1 2; 23 m 10. 0.05 4.
c
c ... define master surface between wall and soil elements
c
sii- -2; 1 2; 1 2; 29 m 0. 0.05 4.
c
c ... define material used for part 5e
c
mate 3
c
c ... end definition of part 5e
c
end
c
c ... Information for part 5f
c
start
c
c ... define index space for concrete facing - top element
c
1 3; 1 2; 1 4;
2.85 3.0
0. 0.1                         -
5.85 6.60
c
c ... define slave surface at top with roof
c
sii- 1 2; 1 2; -2; 33 s 3. 0.05 0.
c
c ... define slave surface at bottom of element
c
sii- 1 2; 1 2; -1; 18 s 3. 0.05 10.
c
c ... define master surface with reinforcement
c
sii+ -2; 1 2; 1 2; 24 m 10. 0.05 4.
c
c ... define master surface between wall and soil elements
c
sii- -2; 1 2; 1 2; 30 m 0. 0.05 4.
c
c ... fix top of this facing element in x-direction
c
b 1 1 2 1 2 2 100000
```

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```
c
c ... define material used in part 5f
c
mate 3
c
c ... end definition of part 5f
c
end
c
c ... Information for part 6
c
start
c
c ... define index space for elastic elements to right of mesh
c
1 3; 1 2; 1 11;
8.0 8.5
0. 0.1
0. 6.6
c
c ... define master surface between soil and rigid rhs
c
sii- -1; 1 2; 1 2; 31 m 10. 0. 4.
c
c ... define boundary conditions for rigid rhs
c
b  1 1 1   2 2 2   111111
c
c ... define material used for part 6
c
mate 3
c
c ... end definition of part 6
c
end
c
c ... Information for part 7
c
start
c
c define index space for roof
c
1 2; 1 2; 1 2;
2.0 3.15
0. 0.1
6.6 7.0
c
c ... fix roof in all directions
c
b 1 1 1   2 2 2  111111
c
c ... define master surface between roof and upper facing
c
sii- 1 2; 1 2; -1; 33 m  3. 0.05 10.
```

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```
c
c ... define material used for part 7
c
mate 3
c
c ... end definition of part 7
c
end
c
c ... define material properties for soil (material #1)
c
mat 1  25
k      4.6e8
g      2.75Ee8
c  alpha  0.
alpha 8.0e3
gamma  0.
c theta  0.2729
theta  0.263
beta   9.718e-8
r      2.5
d      9.718e-8
w      0.066
x0     1.3e6
nplot  3
ltype  1
t      -6.895e3
ro     2000.
c
c ... end definition of material properties for soil
c
endmat
c
c ... define material properties for reinforcing (material #2)
c
mat 2  3
e      3.7e7
pr     0.4
sigy   3.6e6
etan   3.7e5
beta   0.
ro     1000.
c
c ... end definition of material properties for reinforcing
c
endmat
c
c ... define material properties for facing, roof and right hand side
c      (Material #3)
c
mat 3  1
e      2.07e10
pr     C.25
ro     2720.
```

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```
c
c ... end definition of material properties for facing roof and rhs
c
endmat
c
c ... end ingrid
c
end


c
c
c   ... interactive commands necessary for generation of DYNA input deck
c
c
c
c   ... remove redundant nodes between parts
c
tp 0.001
c
c   ... additional interactive commands may be used to check the mesh
c
c
c   ... generate DYNA input file
c
cont
```

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C. EXAMPLE OF DYNA3D INPUT FILE

The following is an example of a DYNA3D input file. Lines beginning with "*comment*" were added by the authors. Lines beginning with just a "*" are comments generated by INGRID. Input data not generated by INGRID are clearly marked by *comment* lines.

```
parametric study - base input file (plane strain)                    88 large
*                                                                     88 large
*
*----------------- ANALYSIS INPUT DATA FOR DYNA3D 88 -----------------*
* Generated with INGRID  version  10/17/89 by Robert Rainsberger.
*
*
*-------------------------- CONTROL CARD #1 --------------------------*
*
* number of materials[1] nodal points[2] solid hexahedron elements[3] beam
* elements[4] 4-node shell elements[5] 8-node solid shell elements[6]
    3      3520      1309          0          0          0
*
*-------------------------- CONTROL CARD #2 --------------------------*
*
* number of time history blocks for nodes[1] hexahedron elements[2] beam
* elements[3] shell elements[4] thick shell elements[5] and report interval[6]
    0    0    0    0    0    0
*comment* The number of time history blocks for nodes and elements has been
*comment* added by hand in this study, not generated by INGRID.  The data for
*comment* Analysis PS1 are shown below.
   15   26    0    0    0    0
*comment*
*
*-------------------------- CONTROL CARD #3 --------------------------*
*
* number of nodes in DYNA3D-JOY interface[1] number of sliding boundary
* planes[2] sliding boundary planes w/ failure[3] points in density vs depth
* curve[4] brode function flag[5] number of rigid body merge cards[6]
* nodal coordinate format[7]
    0    0    0    0    0    0e20.9
*
*-------------------------- CONTROL CARD #4 --------------------------*
*
* number of load curves[1] concentrated nodal loads[2] element sides having
* pressure loads applied[3] velocity/acceleration boundary condition cards[4]
```

```
* rigid walls (stonewalls)[5] nodal constraint cards[6] initial condition
* parameter[7] sliding interfaces[8] base acceleration in x[9] y[10] and
* z-direction[11] angular velocity about x[12] y[13] and z-axis[14] number of
* solid hexahedron elements for momentum deposit[15] detonation points[16]
   35    0    0   68    0    0    0   33    0    0    1    0    0    0    0    0
*
*--------------------------- CONTROL CARD #5 ---------------------------*
*
* termination time[1] time history dump interval[2] complete dump interval[3]
* time steps between restart dumps[4] time steps between running restart
* dumps[5] initial time step[6] sliding interface penalty factor[7] thermal
* effects option[8] default viscosity flag[9] computed time step factor[10]
 8.000E-02 4.000E-02 4.000E-02    0    0 0.000E+00 0.000E+00    0    0 0.000E+00
*
*--------------------------- CONTROL CARD #6 ---------------------------*
*
* number of joint definitions[1] rigid bodies with extra nodes[2] shell-
* solid interfaces[3] tie-breaking shell slidelines[4] tied node sets with
* failure[5] limiting time step load curve number[6] springs-dampers-masses
* flag[7] rigid bodies with inertial properties[8] dump shell strain flag[9]
* shadow burn flag[10] dump hydro variables flag[11] shell update[12]
* thickness[13] and theory options[14] number of nonreflecting
* boundary segments[15]
    0    0    0    0    0    0    0    0    0    0    0    0    0    4
*
*--------------------------- CONTROL CARD #7 ---------------------------*
*
* number of point constraint nodes[1] coordinate systems for constraint
* nodes[2] minimum step factor[3] number of beam integration rules[4]
* maximum integration points for beams[5] number of shell integration rules[6]
* maximum integration points for shells[7] relaxation iterations between
* checks[8] relaxation tolerance[9] dynamic relaxation factor[10] dynamic
* relaxation time step factor[11] 4-node shell time step option[12]
    0    0 0.000E+00    0    0    0    0  250 1.000E-04 9.950E-01 0.000F+00    0
*
*--------------------------- CONTROL CARD #8 ---------------------------*
*
* plane stress plasticity[1] printout flag[2] number of 1D slidelines[3]
    1    0    0
*comment* the mass proportional rayleigh damping term must be input by hand
*comment* in cols 21-30 on the above line since this cannot be done by INGRID.
*comment* the data for analysis PS1 is shown below:
    1    0    0    1.000e+01
*comment*
*
*--------------------------- MATERIAL CARDS ---------------------------*
*
    1  252.0000E+03    0  00.0000E+00   00.0000E+000.0000E+00    0    0    0
material type # 25 (invicid two invariant geologic cap model)
 4.600E+08 2.758E+08 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
 8.000E+03 2.630E-01 0.000E+00 9.718E-08 2.500E+00 0.000E+00 0.000E+00 0.000E+00
 9.718E-08 6.600E-02 1.300E+06 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
 3.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
 1.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
```

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```
-6.895E+03 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
        2    31.0000E+03       0    00.0000E+00      00.0000E+000.0000E+00      0       0       0
material type # 3 (Kinematic/Isotropic elastic-plastic)
  3.700E+07 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
  4.000E-01 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
  3.600E+06 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
  3.700E+05 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
  0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
  0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
        3    12.7200E+03       0    00.0000E+00      00.0000E+000.0000E+00      0       0       0
material type # 1 (elastic)
  2.070E+10 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
  2.500E-01 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
  0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
  0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
  0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
  0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
*
*------------------------- NODE DEFINITIONS -------------------------*
*
        1    7. 0.0000000000000E+00 0.0000000000000E+00 ^ 0000000000000E+00    7.
        2    2. 0.0000000000000E+00 0.0000000000000E+00 �
0000002384186E-01    7.
        3    7. 0.0000000000000E+00 1.0000000149012E-01 0.0000000000000E+00    7.
        4    2. 0.0000000000000E+00 1.0000000149012E-01 6.0000002384186E-01    7.
*comment*
*comment* data for nodes 5-3516 are omitted so save space
*comment*
     3517    7. 3.1500000953674E+00 0.0000000000000E+00 6.5999999046326E+00    7.
     3518    7. 3.1500000953674E+00 0.0000000000000E+00 7.0000000000000E+00    7.
     3519    7. 3.1500000953674E+00 1.0000000149012E-01 6.5999999046326E+00    7.
     3520    7. 3.1500000953674E+00 1.0000000149012E-01 7.0000000000000E+00    7.
*
*------------------ ELEMENT CARDS FOR SOLID ELEMENTS ------------------*
*
        1    1       1       5       7       3       2       6       8       4
        2    1       5       9      11       7       6      10      12       8
        3    1       9      13      15      11      10      14      16      12
        4    1      13      17      19      15      14      18      20      16
*comment*
*comment* data for elements 5-1305 are omitted so save space
*comment*
     1306    3    3477    3499    3510    3488    3478    3500    3511    3489
     1307    3    3456    3478    3489    3467    3457    3479    3490    3468
     1308    3    3478    3500    3511    3489    3479    3501    3512    3490
     1309    3    3513    3517    3519    3515    3514    3518    3520    3516
*comment*
*comment*
*comment* Node time history blocks and element time history blocks were entered by
*comment* hand in this study.  The data for analysis PS1 are shown below:
*comment*
*comment**
*-------------------------NODE TIME HISTORY BLOCKS-------------------------*
*
      109      109     3303    3303    3306    3306    3327    3327    3330    3330
```

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| 3351 | 3351 | 3354 | 3354 | 3375 | 3375 | 3378 | 3378 | 3399 | 3399 |
| 3402 | 3402 | 3423 | 3423 | 3426 | 3426 | 911 | 911 | 879 | 879 |

```
*
*------------------ SOLID ELEMENT TIME HISTORY BOCKS -------------------*
*
```

360	374	1203	1203	1237	1237	645	645	675	675
705	705	735	735	765	765	795	795	825	825
855	855	885	885	915	915	945	945	975	975
1005	1005	1035	1035	1065	1065	1095	1095	1125	1125
1155	1155	285	285	300	300	315	315	330	330
345	345								

```
*comment*
*comment* load curve definitions are generated by INGRID
*comment*
*
*---------------------- LOAD CURVE DEFINITIONS --------------------------*
*
    1    5
 0.000E+00 0.000E+00
 0.200E-01 0.100E+00
 0.600E-01 0.900E+00
 0.800E-01 0.100E+01
 0.100E+02 0.100E+01
    2   11
 0.000E+00 0.000E+00
 0.839E-01 0.000E+00
 0.849E-01 0.100E+01
 0.889E-01 0.886E+00
 0.939E-01 0.781E+00
 0.104E+00 0.599E+00
 0.134E+00 0.221E+00
 0.184E+00-0.590E-01
 0.284E+00-0.127E+00
 0.500E+00 0.000E+00
 0.200E+01 0.000E+00
    3   11
 0.000E+00 0.000E+00
 0.830E-01 0.000E+00
 0.839E-01 0.100E+01
 0.880E-01 0.874E+00
 0.930E-01 0.760E+00
 0.103E+00 0.564E+00
 0.133E+00 0.174E+00
 0.183E+00-0.865E-01
 0.283E+00-0.116E+00
 0.500E+00 0.000E+00
 0.200E+01 0.000E+00
    4   11
 0.000E+00 0.000E+00
 0.821E-01 0.000E+00
 0.829E-01 0.100E+01
 0.871E-01 0.860E+00
 0.921E-01 0.736E+00
 0.102E+00 0.525E+00
```

```
0.132E+00  0.126E+00
0.182E+00 -0.109E+00
0.282E+00 -0.102E+00
0.500E+00  0.000E+00
0.200E+01  0.000E+00
     5    11
0.000E+00  0.000E+00
0.817E-01  0.000E+00
0.824E-01  0.100E+01
0.367E-01  0.853E+00
0.917E-01  0.723E+00
0.102E+00  0.505E+00
0.132E+00  0.121E+00
0.182E+00 -0.117E+00
0.282E+00 -0.942E-01
0.500E+00  0.000E+00
0.200E+01  0.000E+00
     6    11
0.000E+00  0.000E+00
0.814E-01  0.000E+00
0.821E-01  0.100E+01
0.864E-01  0.848E+00
0.914E-01  0.714E+00
0.101E+00  0.491E+00
0.131E+00  0.870E-01
0.181E+00 -0.122E+00
0.281E+00 -0.886E-01
0.500E+00  0.000E+00
0.200E+01  0.000E+00
     7    11
0.000E+00  0.000E+00
0.813E-01  0.000E+00
0.820E-01  0.100E+01
0.863E-01  0.846E+00
0.913E-01  0.710E+00
0.101E+00  0.484E+00
0.131E+00  0.798E-01
0.181E+00 -0.124E+00
0.281E+00 -0.860E-01
0.500E+00  0.000E+00
0.200E+01  0.000E+00
     8    11
0.000E+00  0.000E+00
0.811E-01  0.000E+00
0.818E-01  0.100E+01
0.861E-01  0.843E+00
0.911E-01  0.704E+00
0.101E+00  0.476E+00
0.131E+00  0.707E-01
0.181E+00 -0.126E+00
0.281E+00 -0.826E-01
0.500E+00  0.000E+00
0.200E+01  0.000E+00
     9    11
```

123

```
0.000E+00  0.000E+00
0.810E-01  0.000E+00
0.817E-01  0.100E+01
0.860E-01  0.840E+00
0.910E-01  0.700E+00
0.101E+00  0.470E+00
0.131E+00  0.640E-01
0.181E+00 -0.128E+00
0.281E+00 -0.801E-01
0.500E+00  0.000E+00
0.200E+01  0.000E+00
   10    11
0.000E+00  0.000E+00
0.808E-01  0.000E+00
0.815E-01  0.100E+01
0.858E-01  0.836E+00
0.908E-01  0.692E+00
0.101E+00  0.457E+00
0.131E+00  0.507E-01
0.181E+00 -0.131E+00
0.281E+00 -0.749E-01
0.500E+00  0.000E+00
0.200E+01  0.000E+00
   11    11
0.000E+00  0.000E+00
0.806E-01  0.000E+00
0.813E-01  0.100E+01
0.856E-01  0.831E+00
0.906E-01  0.683E+00
0.101E+00  0.444E+00
0.131E+00  0.386E-01
0.181E+00 -0.132E+00
0.281E+00 -0.702E-01
0.500E+00  0.000E+00
0.200E+01  0.000E+00
   12    11
0.000E+00  0.000E+00
0.805E-01  0.000E+00
0.812E-01  0.100E+01
0.855E-01  0.829E+00
0.905E-01  0.680E+00
0.101E+00  0.439E+00
0.131E+00  0.334E-01
0.181E+00 -0.133E+00
0.281E+00 -0.692E-01
0.500E+00  0.000E+00
0.200E+01  0.000E+00
   13    11
0.000E+00  0.000E+00
0.804E-01  0.000E+00
0.810E-01  0.100E+01
0.854E-01  0.826E+00
0.904E-01  0.675E+00
0.100E+00  0.432E+00
```

124

```
0.130E+00  0.271E-01
0.180E+00 -0.134E+00
0.280E+00 -0.657E-01
0.500E+00  0.000E+00
0.200E+01  0.000E+00
      14    11
0.000E+00  0.000E+00
0.803E-01  0.000E+00
0.810E-01  0.100E+01
0.853E-01  0.824E+00
0.903E-01  0.672E+00
0.100E+00  0.428E+00
0.130E+00  0.226E-01
0.180E+00 -0.134E+00
0.280E+00 -0.639E-01
0.500E+00  0.000E+00
0.200E+01  0.000E+00
      15    11
0.000E+00  0.000E+00
0.802E-01  0.000E+00
0.808E-01  0.100E+01
0.852E-01  0.821E+00
0.902E-01  0.666E+00
0.100E+00  0.419E+00
0.130E+00  0.146E-01
0.180E+00 -0.135E+00
0.280E+00 -0.608E-01
0.500E+00  0.000E+00
0.200E+01  0.000E+00
      16    11
0.000E+00  0.000E+00
0.801E-01  0.000E+00
0.807E-01  0.100E+01
0.851E-01  0.818E+00
0.901E-01  0.662E+00
0.100E+00  0.412E+00
0.130E+00  0.840E-02
0.180E+00 -0.135E+00
0.280E+00 -0.583E-01
0.500E+00  0.000E+00
0.200E+01  0.000E+00
      17    11
0.000E+00  0.000E+00
0.801E-01  0.000E+00
0.807E-01  0.100E+01
0.851E-01  0.817E+00
0.901E-01  0.660E+00
0.100E+00  0.409E+00
0.130E+00  0.620E-02
0.180E+00 -0.135E+00
0.280E+00 -0.574E-01
0.500E+00  0.000E+00
0.200E+01  0.000E+00
      18    11
```

125

```
0.000E+00  0.000E+00
0.800E-01  0.000E+00
0.806E-01  0.100E+01
0.850E-01  0.816E+00
0.900E-01  0.658E+00
0.100E+00  0.407E+00
0.130E+00  0.390E-02
0.180E+00 -0.135E+00
0.280E+00 -0.565E-01
0.500E+00  0.000E+00
0.200E+01  0.000E+00
     19    11
0.000E+00  0.000E+00
0.800E-01  0.000E+00
0.806E-01  0.100E+01
0.850E-01  0.816E+00
0.900E-01  0.657E+00
0.100E+00  0.405E+00
0.130E+00  0.270E-02
0.180E+00 -0.135E+00
0.280E+00 -0.560E-01
0.500E+00  0.000E+00
0.200E+01  0.000E+00
     20    11
0.000E+00  0.000E+00
0.800E-01  0.000E+00
0.806E-01  0.100E+01
0.850E-01  0.815E+00
0.900E-01  0.656E+00
0.100E+00  0.404E+00
0.130E+00  0.160E-02
0.180E+00 -0.135E+00
0.280E+00 -0.556E-01
0.500E+00  0.000E+00
0.200E+01  0.000E+00
     21    11
0.000E+00  0.000E+00
0.800E-01  0.000E+00
0.806E-01  0.100E+01
0.850E-01  0.816E+00
0.900E-01  0.657E+00
0.100E+00  0.405E+00
0.130E+00  0.270E-02
0.180E+00 -0.135E+00
0.280E+00 -0.560E-01
0.500E+00  0.000E+00
0.200E+01  0.000E+00
     22    11
0.000E+00  0.000E+00
0.800E-01  0.000E+00
0.806E-01  0.100E+01
0.850E-01  0.816E+00
0.900E-01  0.658E+00
0.100E+00  0.407E+00
```

126

```
0.130E+00 0.390E-02
0.180E+00-0.135E+00
0.280E+00-0.565E-01
0.500E+00 0.000E+00
0.200E+01 0.000E+00
   23    11
0.000E+00 0.000E+00
0.801E-01 0.000E+00
0.807E-01 0.100E+01
0.851E-01 0.817E+00
0.901E-01 0.660E+00
0.100E+00 0.409E+00
0.130E+00 0.620E-02
0.180E+00-0.135E+00
0.280E+00-0.574E-01
0.500E+00 0.000E+00
0.200E+01 0.000E+00
   24    11
0.000E+00 0.000E+00
0.801E-01 0.000E+00
0.807E-01 0.100E+01
0.851E-01 0.818E+00
0.901E-01 0.662E+00
0.100E+00 0.412E+00
0.130E+00 0.840E-02
0.180E+00-0.135E+00
0.280E+00-0.583E-01
0.500E+00 0.000E+00
0.200E+01 0.000E+00
   25    11
0.000E+00 0.000E+00
0.802E-01 0.000E+00
0.808E-01 0.100E+01
0.852E-01 0.821E+00
0.902E-01 0.666E+00
0.100E+00 0.419E+00
0.130E+00 0.146E-01
0.180E+00-0.135E+00
0.280E+00-0.608E-01
0.500E+00 0.000E+00
0.200E+01 0.000E+00
   26    11
0.000E+00 0.000E+00
0.803E-01 0.000E+00
0.810E-01 0.100E+01
0.853E-01 0.824E+00
0.903E-01 0.672E+00
0.100E+00 0.428E+00
0.130E+00 0.226E-01
0.180E+00-0.134E+00
0.280E+00-0.639E-01
0.500E+00 0.000E+00
0.200E+01 0.000E+00
   27    11
```

127

```
0.000E-00  0.000E+00
0.304E-01  0.000E+00
0.810E-01  0.100E+01
0.854E-01  0.826E+00
0.904E-01  0.675E+00
0.100E+00  0.432E+00
0.130E+00  0.271E-01
0.180E+00 -0.134E+00
0.280E+00 -0.657E-01
0.500E+00  0.000E+00
0.200E+01  0.000E+00
   28    11
0.000E+00  0.000E+00
0.805E-01  0.000E+00
0.812E-01  0.100E+01
0.855E-01  0.829E+00
0.905E-01  0.680E+00
0.101E+00  0.439E+00
0.131E+00  0.334E-01
0.181E+00 -0.133E+00
0.281E+00 -0.682E-01
0.500E+00  0.000E+00
0.200E+01  0.000E+00
   29    11
0.000E+00  0.000E+00
0.806E-01  0.000E+00
0.813E-01  0.100E+01
0.856E-01  0.831E+00
0.906E-01  0.683E+00
0.101E+00  0.444E+00
0.131E+00  0.386E-01
0.181E+00 -0.132E+00
0.281E+00 -0.702E-01
0.500E+00  0.000E+00
0.200E+01  0.000E+00
   30    11
0.000E+00  0.000E+00
0.808E-01  0.000E+00
0.815E-01  0.100E+01
0.858E-01  0.836E+00
0.908E-01  0.692E+00
0.101E+00  0.457E+00
0.131E+00  0.507E-01
0.181E+00 -0.131E+00
0.281E+00 -0.749E-01
0.500E+00  0.000E+00
0.200E+01  0.000E+00
   31    11
0.000E+00  0.000E+00
0.810E-01  0.000E+00
0.817E-01  0.100E+01
0.860E-01  0.840E+00
0.910E-01  0.700E+00
0.101E+00  0.470E+00
```

128

```
0.131E+00  0.640E-01
0.181E+00 -0.128E+00
0.281E+00 -0.801E-01
0.500E+00  0.000E+00
0.200E+01  0.000E+00
     32   11
0.000E+00  0.000E+00
0.811E-01  0.000E+00
0.818E-01  0.100E+01
0.861E-01  0.843E+00
0.911E-01  0.704E+00
0.101E+00  0.476E+00
0.131E+00  0.707E-01
0.181E+00 -0.126E+00
0.281E+00 -0.826E-01
0.500E+00  0.000E+00
0.200E+01  0.000E+00
     33   11
0.000E+00  0.000E+00
0.813E-01  0.000E+00
0.820E-01  0.100E+01
0.863E-01  0.846E+00
0.913E-01  0.710E+00
0.101E+00  0.484E+00
0.131E+00  0.798E-01
0.181E+00 -0.124E+00
0.281E+00 -0.860E-01
0.500E+00  0.000E+00
0.200E+01  0.000E+00
     34   11
0.000E+00  0.000E+00
0.314E-01  0.000E+00
0.821E-01  0.100E+01
0.864E-01  0.848E+00
0.914E-01  0.714E+00
0.101E+00  0.491E+00
0.131E+00  0.870E-01
0.181E+00 -0.122E+00
0.282E+00 -0.886E-01
0.500E+00  0.000E+00
0.200E+01  0.000E+00
     35   11
0.000E+00  0.000E+00
0.817E-01  0.000E+00
0.824E-01  0.100E+01
0.867E-01  0.853E+00
0.917E-01  0.723E+00
0.102E+00  0.505E+00
0.132E+00  0.121E+00
0.182E+00 -0.117E+00
0.282E+00 -0.942E-01
0.500E+00  0.000E+00
0.200E+01  0.000E+00
```

129

```
*
  3234    2    4 2.270E+00-1.000E+00 0.000E+00 0.000E+00    0
  3236    2    4 2.270E+00-1.000E+00 0.000E+00 0.000E+00    0
  3237    3    4 3.226E+00-1.000E+00 0.000E+00 0.000E+00    0
  3238    3    4 3.226E+00-1.000E+00 0.000E+00 0.000E+00    0
  3239    4    4 4.591E+00-1.000E+00 0.000E+00 0.000E+00    0
  3240    4    4 4.591E+00-1.000E+00 0.000E+00 0.000E+00    0
  3241    5    4 5.453E+00-1.000E+00 0.000E+00 0.000E+00    0
  3242    5    4 5.453E+00-1.000E+00 0.000E+00 0.000E+00    0
  3243    6    4 6.128E+00-1.000E+00 0.000E+00 0.000E+00    0
  3244    6    4 6.128E+00-1.000E+00 0.000E+00 0.000E+00    0
  3245    7    4 6.468E+00-1.000E+00 0.000E+00 0.000E+00    0
  3246    7    4 6.468E+00-1.000E+00 0.000E+00 0.000E+00    0
  3247    8    4 6.927E+00-1.000E+00 0.000E+00 0.000E+00    0
  3248    8    4 6.927E+00-1.000E+00 0.000E+00 0.000E+00    0
  3249    9    4 7.290E+00-1.000E+00 0.000E+00 0.000E+00    0
  3250    9    4 7.290E+00-1.000E+00 0.000E+00 0.000E+00    0
  3251   10    4 8.075E+00-1.000E+00 0.000E+00 0.000E+00    0
  3252   10    4 8.075E+00-1.000E+00 0.000E+00 0.000E+00    0
  3253   11    4 8.869E+00-1.000E+00 0.000E+00 0.000E+00    0
  3254   11    4 8.869E+00-1.000E+00 0.000E+00 0.000E+00    0
  3255   12    4 9.242E+00-1.000E+00 0.000E+00 0.000E+00    0
  3256   12    4 9.242E+00-1.000E+00 0.000E+00 0.000E+00    0
  3257   13    4 9.715E+00-1.000E+00 0.000E+00 0.000E+00    0
  3258   13    4 9.715E+00-1.000E+00 0.000E+00 0.000E+00    0
  3259   14    4 1.006E+01-1.000E+00 0.000E+00 0.000E+00    0
  3260   14    4 1.006E+01-1.000E+00 0.000E+00 0.000E+00    0
  3261   15    4 1.073E+01-1.000E+00 0.000E+00 0.000E+00    0
  3262   15    4 1.073E+01-1.000E+00 0.000E+00 0.000E+00    0
  3263   16    4 1.129E+01-1.000E+00 0.000E+00 0.000E+00    0
  3264   16    4 1.129E+01-1.000E+00 0.000E+00 0.000E+00    0
  3265   17    4 1.150E+01-1.000E+00 0.000E+00 0.000E+00    0
  3266   17    4 1.150E+01-1.000E+00 0.000E+00 0.000E+00    0
  3267   18    4 1.171E+01-1.000E+00 0.000E+00 0.000E+00    0
  3268   18    4 1.171E+01-1.000E+00 0.000E+00 0.000E+00    0
  3269   19    4 1.183E+01-1.000E+00 0.000E+00 0.000E+00    0
  3270   19    4 1.183E+01-1.000E+00 0.000E+00 0.000E+00    0
  3271   20    4 1.193E+01-1.000E+00 0.000E+00 0.000E+00    0
  3272   20    4 1.193E+01-1.000E+00 0.000E+00 0.000E+00    0
  3273   21    4 1.183E+01-1.000E+00 0.000E+00 0.000E+00    0
  3274   21    4 1.183E+01-1.000E+00 0.000E+00 0.000E+00    0
  3275   22    4 1.171E+01-1.000E+00 0.000E+00 0.000E+00    0
  3276   22    4 1.171E+01-1.000E+00 0.000E+00 0.000E+00    0
  3277   23    4 1.150E+01-1.000E+00 0.000E+00 0.000E+00    0
  3278   23    4 1.150E+01-1.000E+00 0.000E+00 0.000E+00    0
  3279   24    4 1.129E+01-1.000E+00 0.000E+00 0.000E+00    0
  3280   24    4 1.129E+01-1.000E+00 0.000E+00 0.000E+00    0
  3281   25    4 1.073E+01-1.000E+00 0.000E+00 0.000E+00    0
  3282   25    4 1.073E+01-1.000E+00 0.000E+00 0.000E+00    0
  3283   26    4 1.006E+01-1.000E+00 0.0 0E+00 0.000E+00    0
  3284   26    4 1.006E+01-1.000E+00 0.000E+00 0.000E+00    0
  3285   27    4 9.715E+00-1.000E+00 0.000E+00 0.000E+00    0
  3286   27    4 9.715E+00-1.000E+00 0.000E+00 0.000E+00    0
```

```
3287   28    4 9.242E+00-1.000E+00 0.000E+00 0.000E+00      0
3288   28    4 9.242E+00-1.000E+00 0.000E+00 0.000E+00      0
3289   29    4 8.869E+00-1.000E+00 0.000E+00 0.000E+00      0
3290   29    4 8.869E+00-1.000E+00 0.000E+00 0.000E+00      0
3291   30    4 8.075E+00-1.000E+00 0.000E+00 0.000E+00      0
3292   30    4 8.075E+00-1.000E+00 0.000E+00 0.000E+00      0
3293   31    4 7.290E+00-1.000E+00 0.000E+00 0.000E+00      0
3294   31    4 7.290E+00-1.000E+00 0.000E+00 0.000E+00      0
3295   32    4 6.927E+00-1.000E+00 0.000E+00 0.000E+00      0
3296   32    4 6.927E+00-1.000E+00 0.000E+00 0.000E+00      0
3297   33    4 6.468E+00-1.000E+00 0.000E+00 0.000E-00      0
3298   33    4 6.468E+00-1.000E+00 0.000E+00 0.000E+00      0
3299   34    4 6.128E+00-1.000E+00 0.000E+00 0.000E+00      0
3300   34    4 6.128E+00-1.000E+00 0.000E+00 0.000E+00      0
3301   35    4 5.453E+00-1.000E+00 0.000E+00 0.000E+00      0
3302   35    4 5  53E+00-1.000E+00 0.000E+00 0.000E+00      0
*
*-------------------------- SLIDING INTERFACE DEFINITIONS ----------------------*
*
    32      15    3 9.000E-01 9.000E-01 0.000E+00      0      0     00.0E+000.0E+00
    30      15    3 9.000E-01 9.000E 01 0.000E+00      0      0     00.0E+000.0E+00
    30      15    3 9.000E-01 9.000E-01 0.000E+00      0      0     00.0E+000.0E+00
    30      15    3 9.000E-01 9.000E-01 0.000E+00      0      0     00.0E+000.0E+00
    30      15    3 9.000E-01 9.000E-01 0.000E+00      0      0     00.0E+000.0E+00
    30      15    3 9.000E-01 9.000E-01 0.000E+00      0      0     00.0E+000.0E+00
    30      15    3 9.000E-01 9.000E-01 0.000E+00      0      0     00.0E+000.0E+00
    30      15    3 9.000E-01 9.000E-01 0.000E+00      0      0     00.0E+000.0E+00
    30      15    3 9.000E-01 9.000E-01 0.000E+00      0      0     00.0E+000.0E+00
    30      15    3 9.000E-01 9.000E-01 0.000E+00      0      0     00.0E+000.0E+00
    30      15    3 9.000E-01 9.000E-01 0.000E+00      0      0     00.0E+000.0E+00
    30      15    3 9.000E-01 9.000E-01 0.000E+00      0      C     00.0E+000.0E+00
    30      15    3 9.000E-01 9.000E-01 0.000E+00      C      0     00.0E+000.0E+00
    35      30    2 0.000E+00 0.000E+00 0.000E+00      0      0     00.0E+000.0E+00
     2       2    3 1.500E+00 1.500E+00 0.000E+00      0      0     00.0E+000.0E+00
     2       2    3 1.500E+00 1.500E+00 0.000E+00      0      0     00.0E+000.0E+00
     2       2    3 1.500E+00 1.500E+00 0.000E+00      0      0     00.0E+000.0E+00
     2       2    3 1.500E+00 1.500E+00 0.000E+00      0      0     00.0E+000.0E+00
     2       2    3 1.500E+00 1.500E+00 0.000E+00      0      0     00.0E+000.0E+00
     3       3    2 0.000E+00 0.000E+00 0.000E+00      0      0     00.0E+000.0E+00
     3       3    2 0.000E+00 0.000E+00 0.000E+00      0      0     00.0E+000.0E+00
     3       3    2 0.000E+00 0.000E+00 0.000E+00      0      0     00.0E+000.0E+00
     3       3    2 0.000E+00 0.000E+00 0.000E+00      0      0     00.0E+000.0E+00
     3       3    2 0.000E+00 0.000E+00 0.000E+00      0      0     00.0E+000.0E+00
     3       3    2 0.000E+00 0.000E+00 0.000E+00      0      0     00.0E+000.0E+00
     6       3    3 7.000E 01 7.000E-01 0.000E+00      0      0     00.0E+000.0E+00
     6       3    3 7.000E 01 7.000E-01 0.000E+00      0      0     00.0E+000.0E+00
     6       3    3 7.000E-01 7.000E-01 0.000E+00      0      0     00.0E+000.0E+00
     6       3    3 7.000E-01 7.000E-01 0.000E+00      0      0     00.0E+000.0E+00
     6       3    3 7.000E-01 7.000E-01 0.000E+00      0      0     00.0E+000.0E+00
     6       3    3 7.000E-01 7.000E-01 0.000E+00      0      0     00.0E+000.0E+00
    34      10    3 0.000E+00 0.000E+00 0.000E+00      0      0     00.0E+000.0E+00
     2      26    3 1.500E+00 1.500E+00 0.000E+00      0      0     00.0E+000.0E+00
    17       1    3 1.500E+00 1.500E+00 0.000E+00      0      0     00.0E+000.0E+00
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     2    1622    1627    1635    1631
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9	1682	1690	1694	1686

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17	1991	1995	2003	1999
18	1999	2003	2011	2007

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13	583	585	586	584
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26	2066	2074	2078	2070
27	2074	2082	2066	2078

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13	639	641	645	643
14	643	645	649	647
15	647	649	653	651
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23	2290	2298	2302	2294
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11	855	857	861	859
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14	867	869	87	871
15	871	873	877	875

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29	2586	2594	2598	2590
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23	2786	2794	2798	2790
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4	1461	1463	1464	1462
5	1463	1465	1466	1464
6	1465	1467	1468	1466

7	1467	1469	1470	1468
8	1469	1471	1472	1470
9	1471	1473	1474	1472
10	1473	1475	1476	1474
11	1475	1477	1478	1476
12	1477	1479	1480	1478
13	1479	1481	1482	1480
14	1481	1483	1484	1482
15	1483	1485	1486	1484
1	2858	2966	2870	2862
2	2866	2874	2878	2870
3	2874	2882	2886	2878
4	2882	2890	2894	2886
5	2890	2898	2902	2894
6	2898	2906	2910	2902
7	2906	2914	2918	2910
8	2914	2922	2926	2918
9	2922	2930	2934	2926
10	2930	2938	2942	2934
11	2938	2946	2950	2942
12	2946	2954	2958	2950
13	2954	2962	2966	2958
14	2962	2970	2974	2966
15	2970	2978	2982	2974
16	2978	2986	2990	2982
17	2986	2994	2998	2990
18	2994	3002	3006	2998
19	3002	3010	3014	3006
20	3010	3018	3022	3014
21	3018	3026	3030	3022
22	3026	3034	3038	3030
23	3034	3042	3046	3038
24	3042	3050	3054	3046
25	3050	3058	3062	3054
26	3058	3066	3070	3062
27	3066	3074	3078	3070
28	3074	3082	3086	3078
29	3082	3090	3094	3086
30	3090	3098	3102	3094
1	1487	1489	1493	1491
2	1491	1493	1497	1495
3	1495	1497	1501	1499
4	1499	1501	1505	1503
5	1503	1505	1509	1507
6	1507	1509	1513	1511
7	1511	1513	1517	1515
8	1515	1517	1521	1519
9	1519	1521	1525	1523
10	1523	1525	1529	1527
11	1527	1529	1533	1531
12	1531	1533	1537	1535
13	1535	1537	1541	1539
14	1539	1541	1545	1543
15	1543	1545	1549	1547

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1	269	270	302	301
2	301	302	334	333
3	333	334	366	365
4	427	429	430	428
5	428	430	462	461
6	461	462	494	493
7	493	494	526	525
8	525	526	558	557
9	557	558	590	589
10	651	653	654	652
11	652	654	686	685
12	685	686	718	717
13	717	718	750	749
14	749	750	782	781
15	781	782	814	813
16	875	877	878	876
17	876	878	910	909
18	909	910	942	941
19	941	942	974	973
20	973	974	1006	1005
21	1005	1006	1038	1037
22	1099	1101	1102	1100
23	1100	1102	1134	1133
24	1133	1134	1166	1165
25	1165	1166	1198	1197
26	1197	1198	1230	1229
27	1229	1230	1252	1261
28	1323	1325	1326	1324
29	1324	1326	1358	1357
30	1357	1358	1390	1389
31	1389	1390	1422	1421
32	1421	1422	1454	1453
33	1453	1454	1486	1485
34	1547	1549	1550	1548
35	1548	1550	1582	1581
36	1581	1582	1614	1613
1	269	3113	3114	270
2	3113	3117	3118	3114
3	3117	3121	3122	3118
4	3121	3125	3126	3122
5	3125	3129	3130	3126
6	3129	3133	3134	3130
7	3133	3137	3138	3134
8	3137	3141	3142	3138
9	3141	3145	3146	3142
10	3145	3149	3150	3146
11	3149	3153	3154	3150
12	3153	3157	3158	3154
13	3157	3161	3162	3158
14	3161	3165	3166	3162
15	3165	3169	3170	3166
16	3169	3173	3174	3170
17	3173	3177	3178	3174
18	3177	3181	3182	3178

19	3181	3185	3186	3182
20	3185	3189	3190	3186
21	3189	3193	3194	3190
22	3193	3197	3198	3194
23	3197	3201	3202	3198
24	3201	3205	3206	3202
25	3205	3209	3210	3206
26	3209	3213	3214	3210
27	3213	3217	3218	3214
28	3217	3221	3222	3218
29	3221	3225	3226	3222
30	3225	3229	3230	3226
1	3327	3331	3339	3335
2	3335	3339	3347	3343
1	3306	3314	3318	3310
2	3314	3322	3326	3318
1	3351	3355	3363	3359
2	3359	3363	3371	3367
1	3330	3338	3342	3334
2	3338	3346	3350	3342
1	3375	3379	3387	3383
2	3383	3387	3395	3391
1	3354	3362	3366	3358
2	3362	3370	3374	3366
1	3399	3403	3411	3407
2	3407	3411	3419	3415
1	3378	3386	3390	3382
2	3386	3394	3398	3390
1	3423	3427	3435	3431
2	3431	3435	3443	3439
1	3402	3410	3414	3406
2	3410	3418	3422	3414
1	1515	1616	- 1620	1619
2	1616	1617	1621	1620
3	1617	1618	1622	1621
1	3319	3322	3324	3320
2	3320	3324	3325	3321
3	3321	3325	3326	3322
1	1963	1864	1868	1867
2	1864	1865	1869	1868
3	1865	1866	1870	1869
1	3343	3347	3348	3344
2	3344	3348	3349	3345
3	3345	3349	3350	3346
1	2111	2112	2116	2115
2	2112	2113	2117	2116
3	2113	2114	2118	2117
1	3367	3371	3372	3368
2	3368	3372	3373	3369
3	3369	3373	3374	3370
1	2359	2360	2364	2363
2	2360	2361	2365	2364
3	2361	2362	2366	2365
1	3391	3395	3396	3392

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2	3392	3396	3397	3393
3	3393	3397	3398	3394
1	2607	2608	2612	2611
2	2608	2609	2613	2612
3	2609	2610	2614	2613
1	3415	3419	3420	3416
2	3416	3420	3421	3417
3	3417	3421	3422	3418
1	2855	2856	2860	2859
2	2856	2857	2861	2860
3	2857	2858	2862	2861
1	3439	3443	3444	3440
2	3440	3444	3445	3441
3	3441	3445	3446	3442
1	119	271	272	120
2	271	303	304	272
3	303	335	336	304
4	367	368	370	369
5	368	431	432	370
6	431	463	464	432
1	3319	3323	3324	3320
2	3320	3324	3325	3321
3	3321	3325	3326	3322
1	463	495	496	464
2	495	527	528	496
3	527	559	560	528
4	591	592	594	593
5	592	655	656	594
6	655	687	688	656
1	3343	3347	3348	3344
2	3344	3348	3349	3345
3	3345	3349	3350	3346
1	687	719	720	638
2	719	751	752	720
3	751	783	784	752
4	815	816	318	317
5	816	879	880	318
6	879	911	912	880
1	3367	3371	3372	3368
2	3368	3372	3373	3369
3	3369	3373	3374	3370
1	911	943	944	912
2	943	975	976	944
3	975	1007	1008	976
4	1039	1040	1042	1041
5	1040	1103	1104	1042
6	1103	1135	1136	1104
1	3391	3395	3396	3392
2	3392	3396	3397	3393
3	3393	3397	3398	3394
1	1135	1167	1168	1136
2	1167	1199	1200	1168
3	1199	1231	1232	1200
4	1263	1264	1266	1265

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5	1264	1327	1328	1266
6	1327	1359	1360	1328
1	3415	3419	3420	3416
2	3416	3420	3421	3417
3	3417	3421	3422	3418
1	1359	1391	1392	1360
2	1391	1423	1424	1392
3	1423	1455	1456	1424
4	1487	1488	1490	1489
5	1488	1551	1552	1490
6	1551	1583	1584	1552
1	3439	3443	3444	3440
2	3440	3444	3445	3441
3	3441	3445	3446	3442
1	3233	3235	3236	3234
2	3234	3236	3238	3237
3	3237	3238	3240	3239
4	3239	3240	3242	3241
5	3241	3242	3244	3243
6	3243	3244	3246	3245
7	3245	3246	3248	3247
8	3247	3248	3250	3249
9	3249	3250	3252	3251
10	3251	3252	3254	3253
11	3253	3254	3256	3255
12	3255	3256	3258	3257
13	3257	3258	3260	3259
14	3259	3260	3262	3261
15	3251	3262	3264	3263
16	3263	3264	3266	3265
17	3265	3266	3268	3267
18	3267	3268	3270	3269
19	3269	3270	3272	3271
20	3271	3272	3274	3273
21	3273	3274	3276	3275
22	3275	3276	3278	3277
23	3277	3278	3280	3279
24	3279	3280	3282	3281
25	3281	3282	3284	3283
26	3283	3284	3286	3285
27	3285	3286	3288	3287
28	3287	3288	3290	3289
29	3289	3290	3292	3291
30	3291	3292	3294	3293
31	3293	3294	3296	3295
32	3295	3296	3298	3297
33	3297	3298	3300	3299
34	3299	3300	3302	3301
1	3447	3448	3459	3458
2	3448	3449	3460	3459
3	3449	3450	3461	3460
4	3450	3451	3462	3461
5	3451	3452	3463	2462
6	3452	3453	3464	3463

7	3453	3454	3465	3464
8	3454	3455	3466	3465
9	3455	3456	3467	3466
10	3156	3457	3468	3467
1	3303	3307	3315	3311
2	3311	3315	3323	3319
1	81	83	84	82
2	83	85	86	84
3	85	87	88	86
4	87	89	90	88
5	89	91	92	90
6	91	93	94	92
7	93	95	96	94
8	95	97	98	96
9	97	99	100	98
10	99	109	110	100
11	109	119	120	110
12	119	241	242	120
13	241	243	244	242
14	243	245	246	244
15	245	247	248	246
16	247	249	250	248
17	249	251	252	250
18	251	253	254	252
19	253	255	256	254
20	255	257	258	256
21	257	259	260	258
22	259	261	262	260
23	261	263	264	262
24	263	265	266	264
25	265	267	268	266
26	267	269	270	268
1	1583	1585	1586	1584
2	1585	1587	1588	1586
3	1587	1589	1590	1588
4	1589	1591	1592	1590
5	1591	1593	1594	1592
6	1593	1595	1596	1594
7	1595	1597	1598	1596
8	1597	1599	1600	1598
9	1599	1601	1602	1600
10	1601	1603	1604	1602
11	1603	1605	1606	1604
12	1605	1607	1608	1606
13	1607	1609	1610	1608
14	1609	1611	1612	1610
15	1611	1613	1614	1612
16	3426	3434	3438	3430
17	3434	3442	3446	3438
1	3513	3515	3519	3517

```
* ---------------- BASE ACCELERATION IN z-DIRECTION ---------------- *
```

1 9.810E+00

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```
*
*---------------------- NONREFLECTING BOUNDARY SEGMENTS ----------------------+
*
      1       1       2       4       3
      2       2      41      42       4
      3      41      61      62      42
      4      61      81      82      62
```

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D. DEFORMED WALL GEOMETRIES

The deformed shape of each wall analyzed in the numerical study (except for PS1 which is shown in Volume 1, page 137) is presented in Figures 93-106. The time at which the deformed mesh is shown varies from 0.41 to 1.03 seconds due to differences in the length of time it took for each wall to stop moving.

148
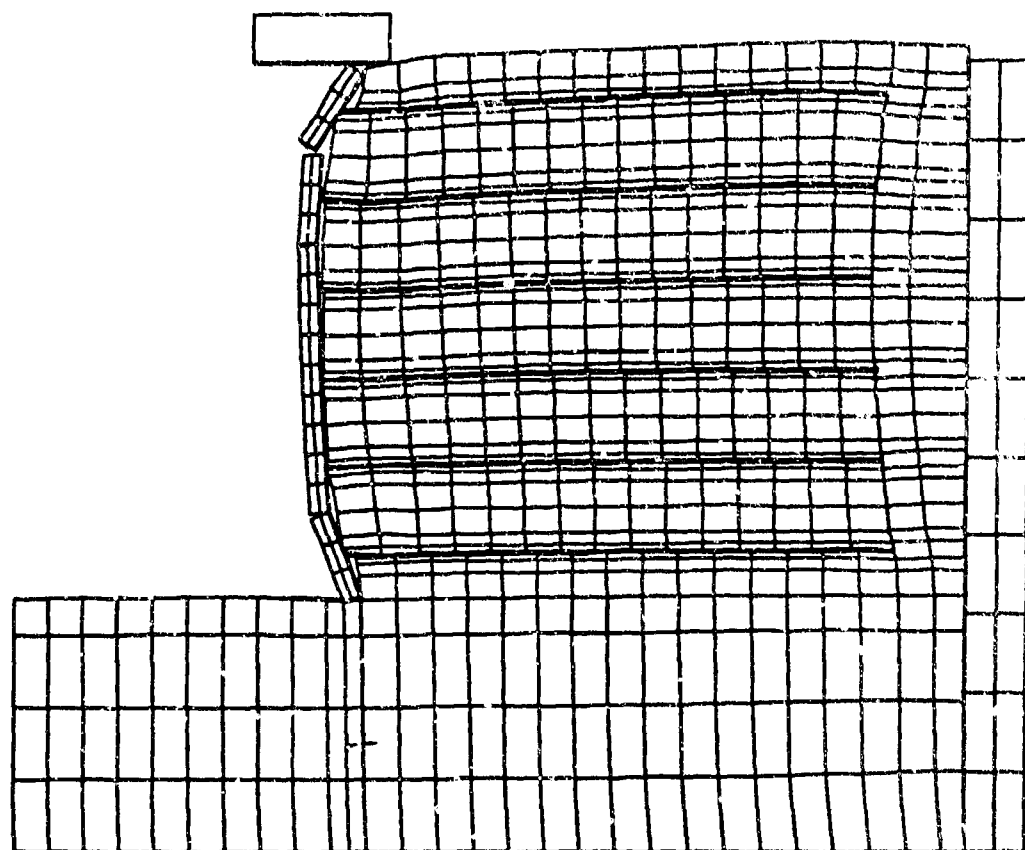
Figure 93. Deformed Shape of Mesh at 0.46 Seconds -
Analysis PS2 (week reinforcement).

149
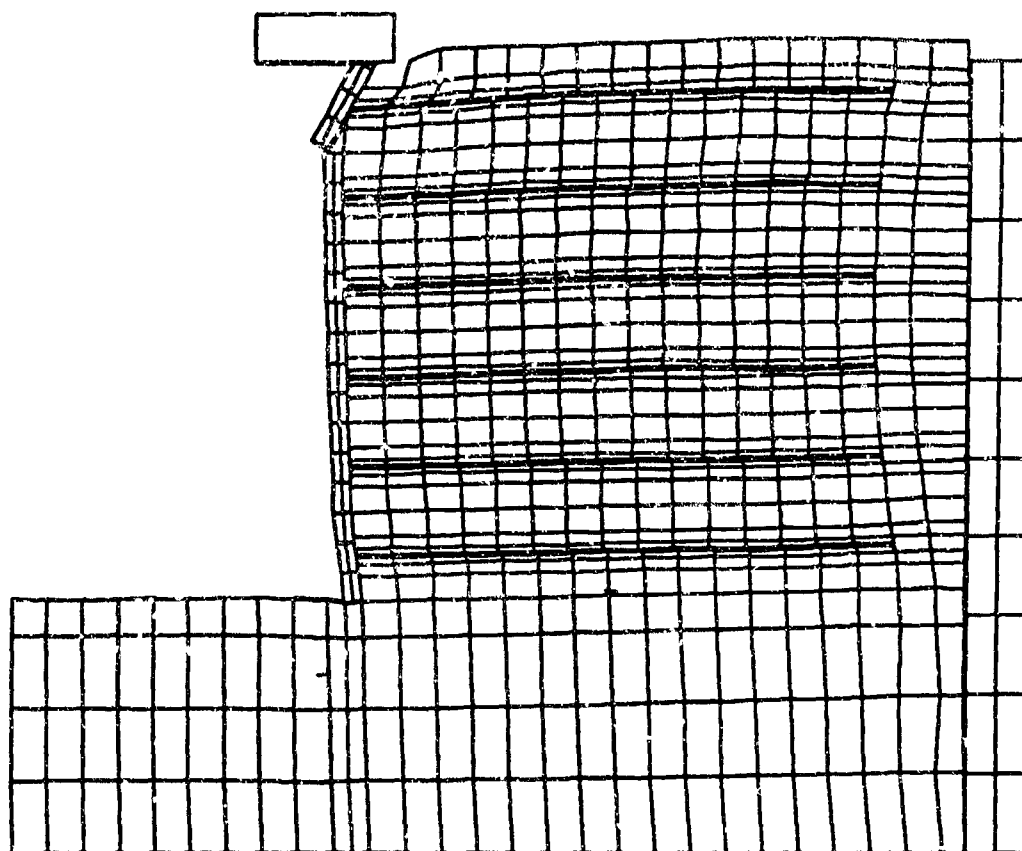
Figure 94. Deformed Shape of Mesh at 0.41 Seconds-
Analysis PS3 (strong reinforcement).

150
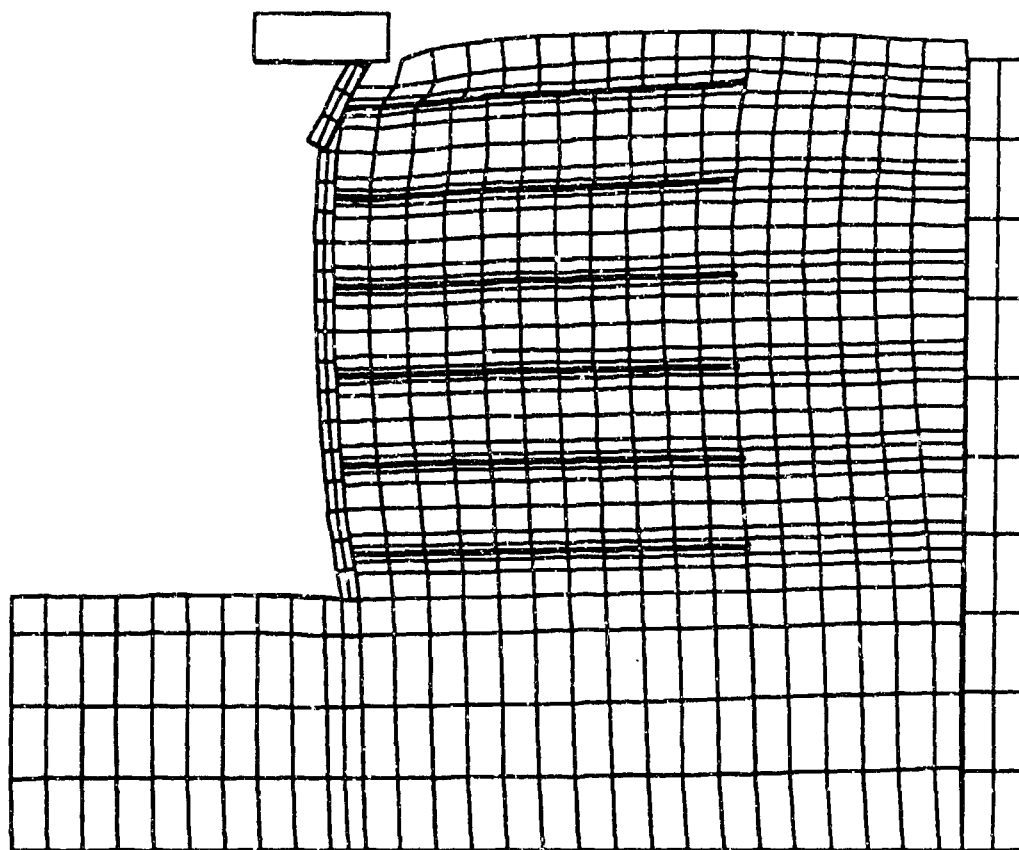
Figure 95.   Deformed Shape of Mesh at 0.41 Seconds-
             Analysis PS4 (short reinforcement).
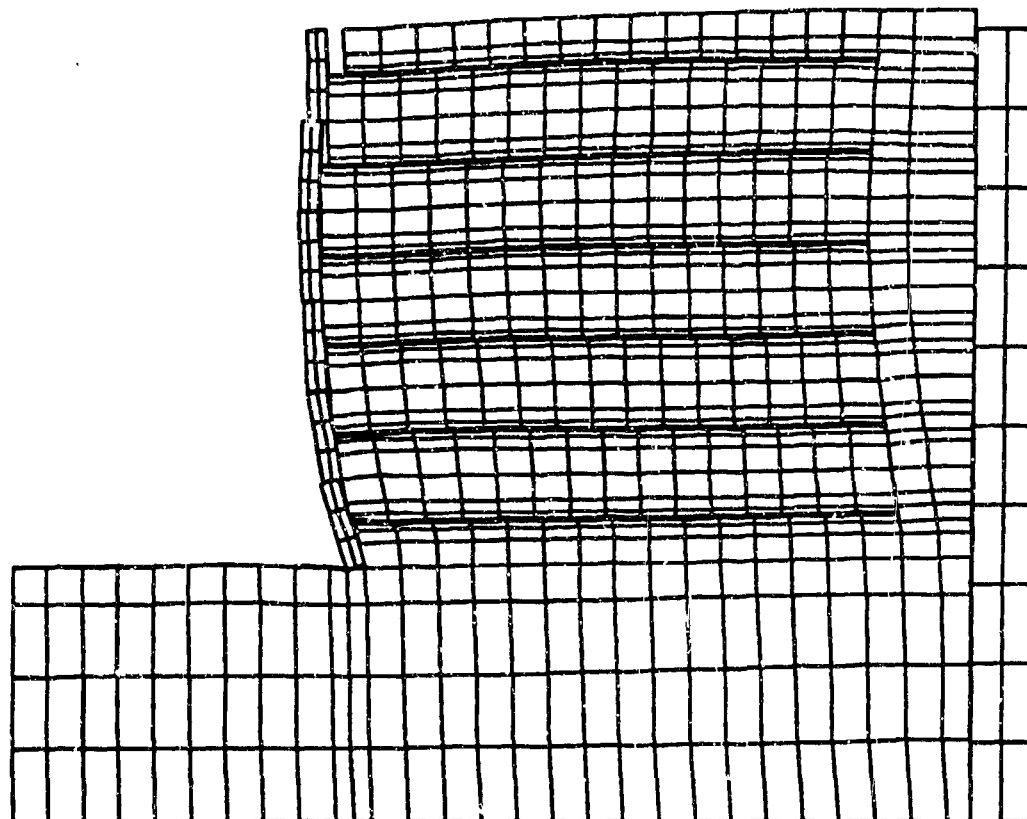
Figure 96. Deformed Shape of Mesh at 0.43 Seconds-
Analysis PS5 (no roof).

152
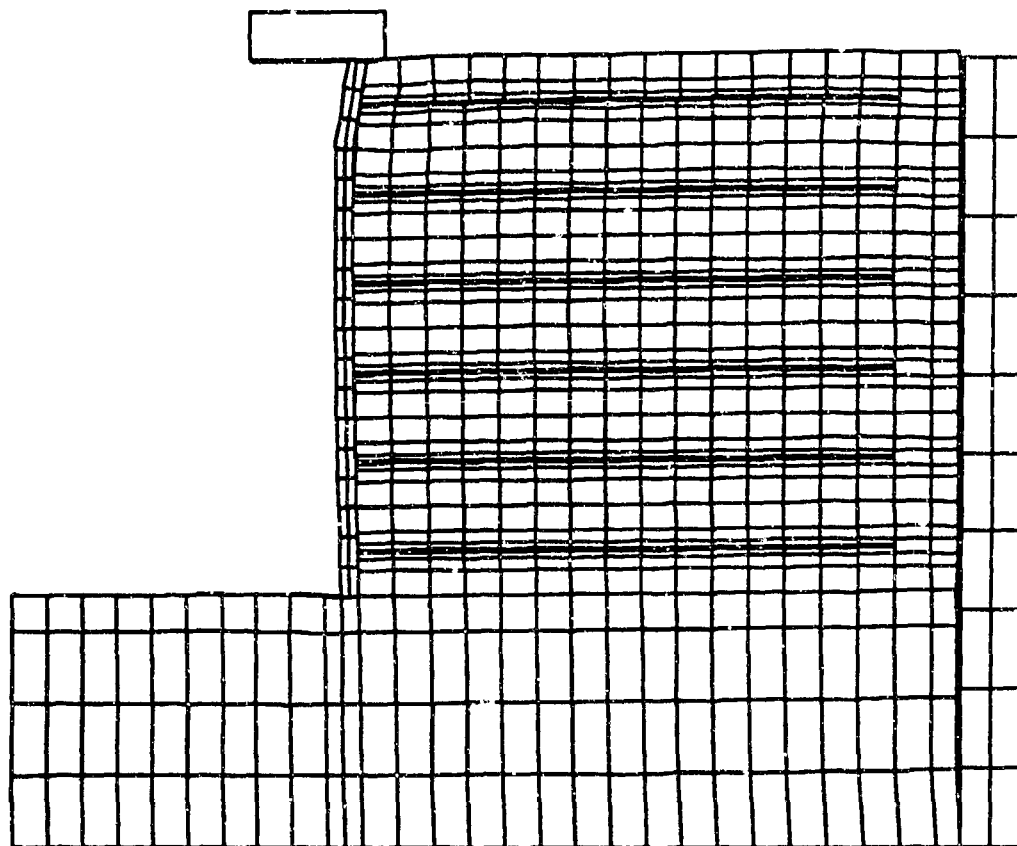
Figure 97. Deformed Shape of Mesh at 0.41 Seconds-
Analysis PS6 (197 lb @ 20 ft).

153
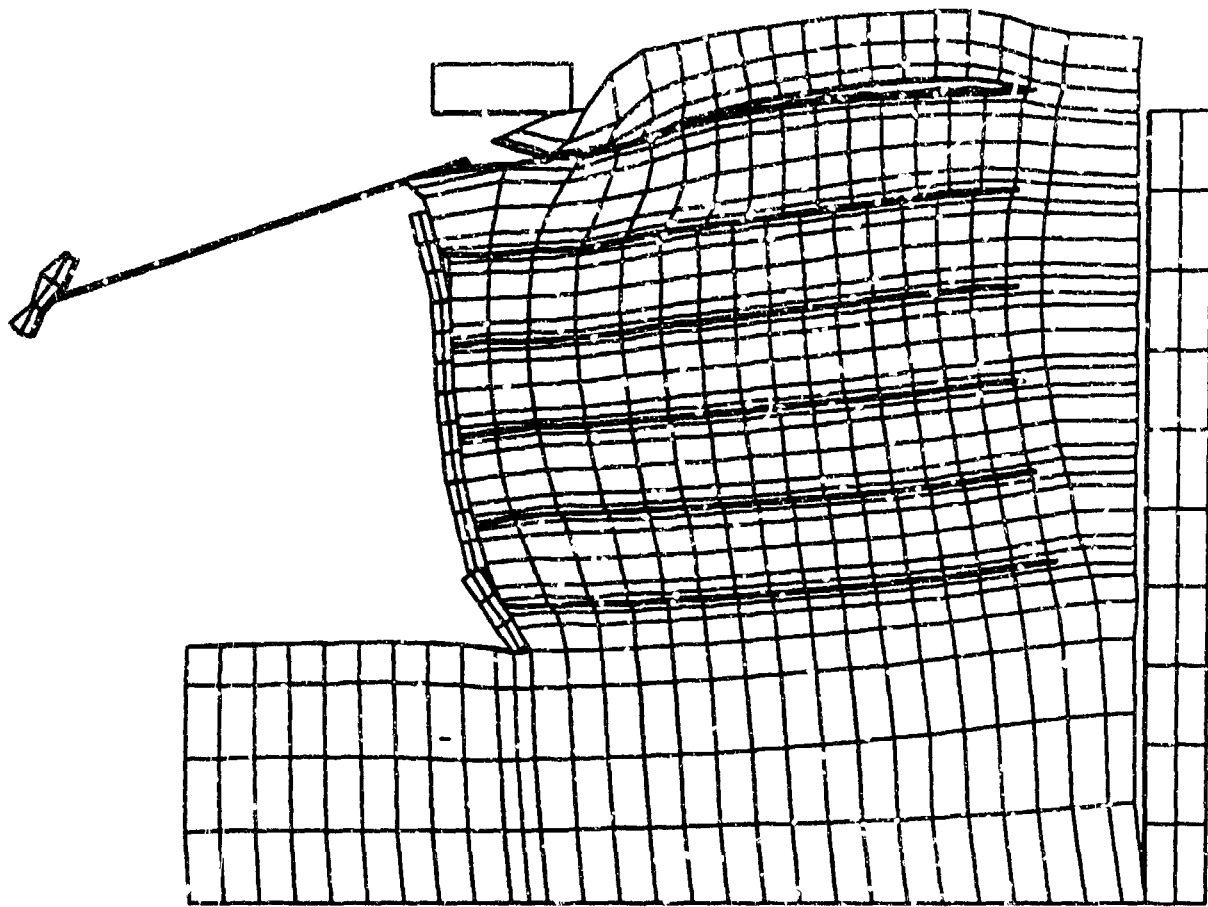
Figure 98.   Deformed Shape of Mesh at 0.31 Seconds-
Analysis PS7 (500 lb @ 10 ft).

154
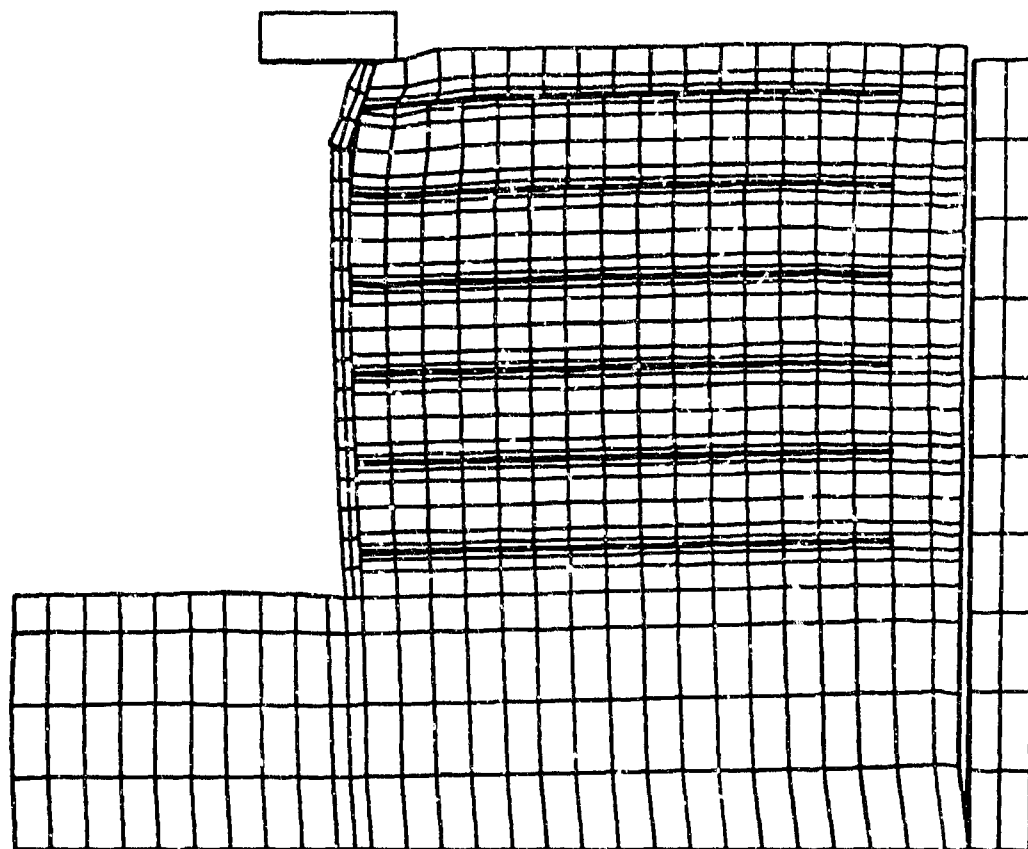
Figure 99.   Deformed Shape of Mesh at 0.41 Seconds-
Analysis PS8 (500 lb @ 20 ft).

155
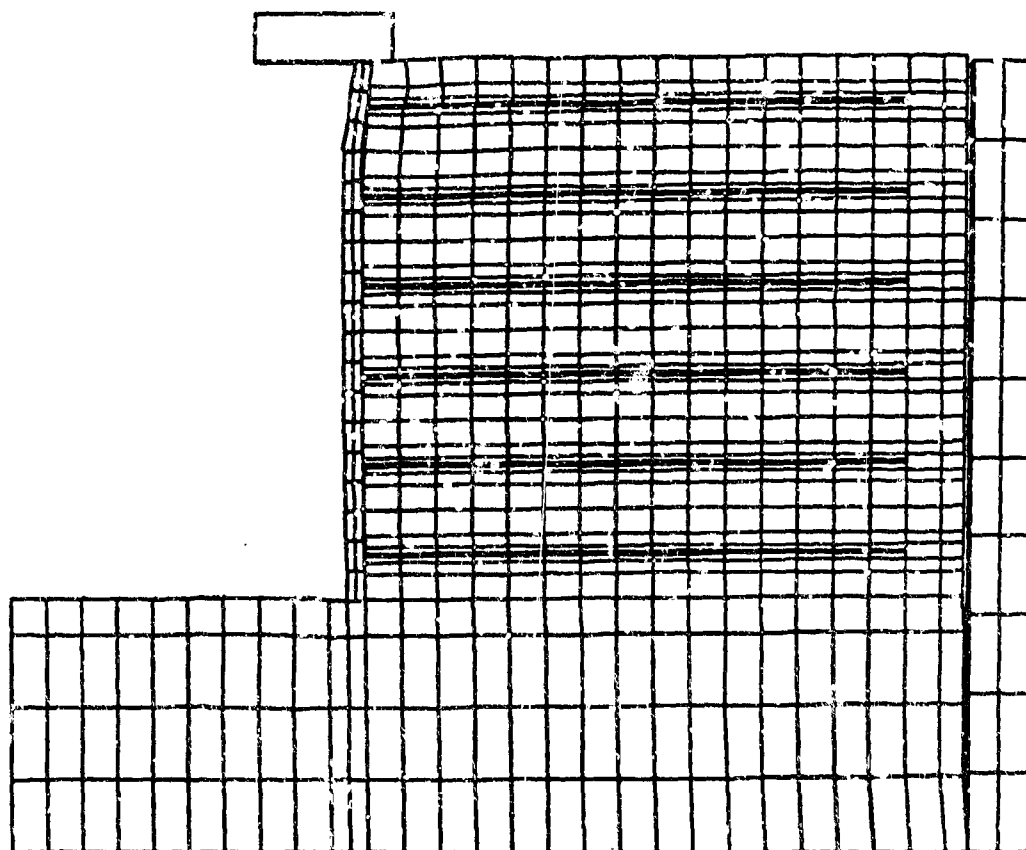
Figure 100. Deformed Shape of Mesh at 0.41 Seconds
Analysis PS9 (500 lb @ 40 ft).

156
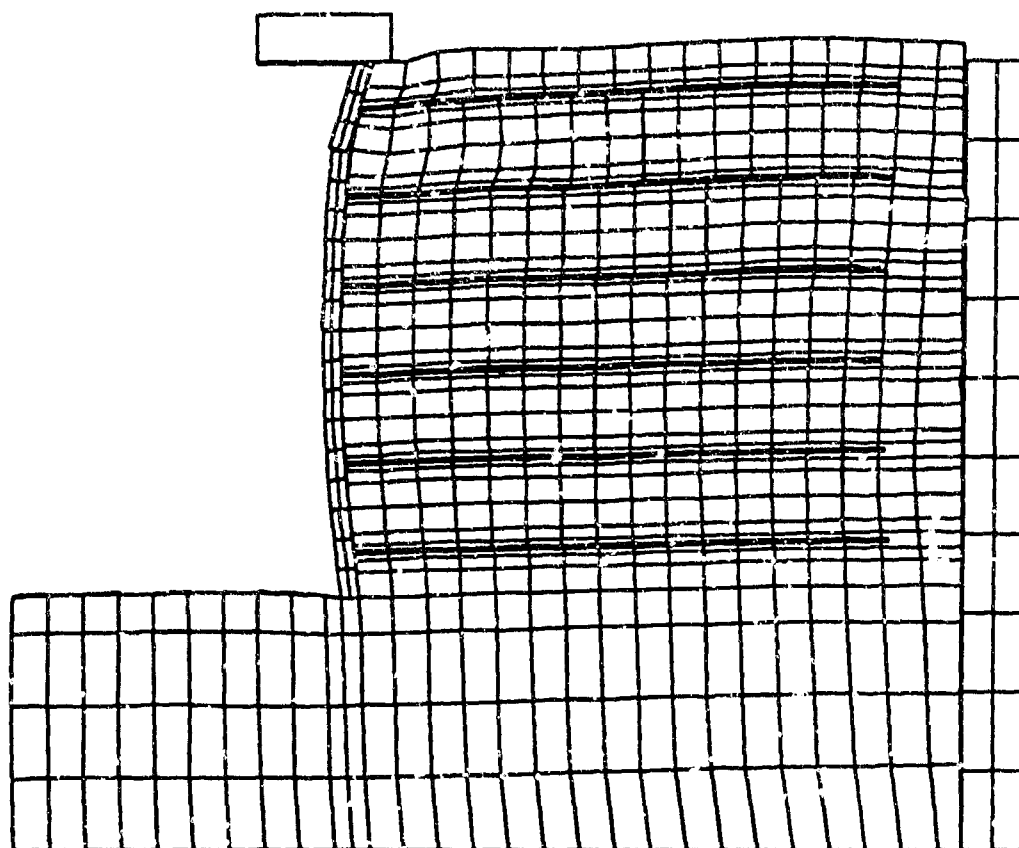
Figure 101. Deformed Shape of Mesh at 0.41 Seconds - Analysis PS1B (weapon @ base).

157
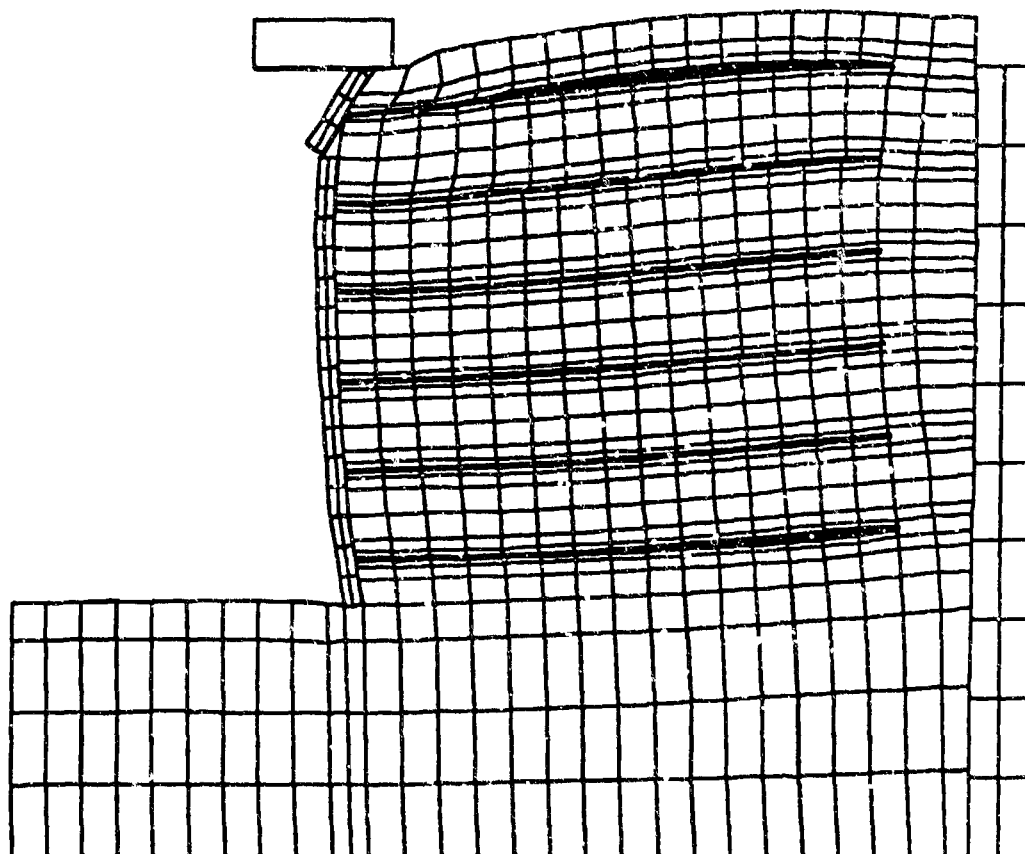
Figure 102. Deformed Shape of Mesh at 1.03 Seconds Analysis PSIN (no gravity).

158
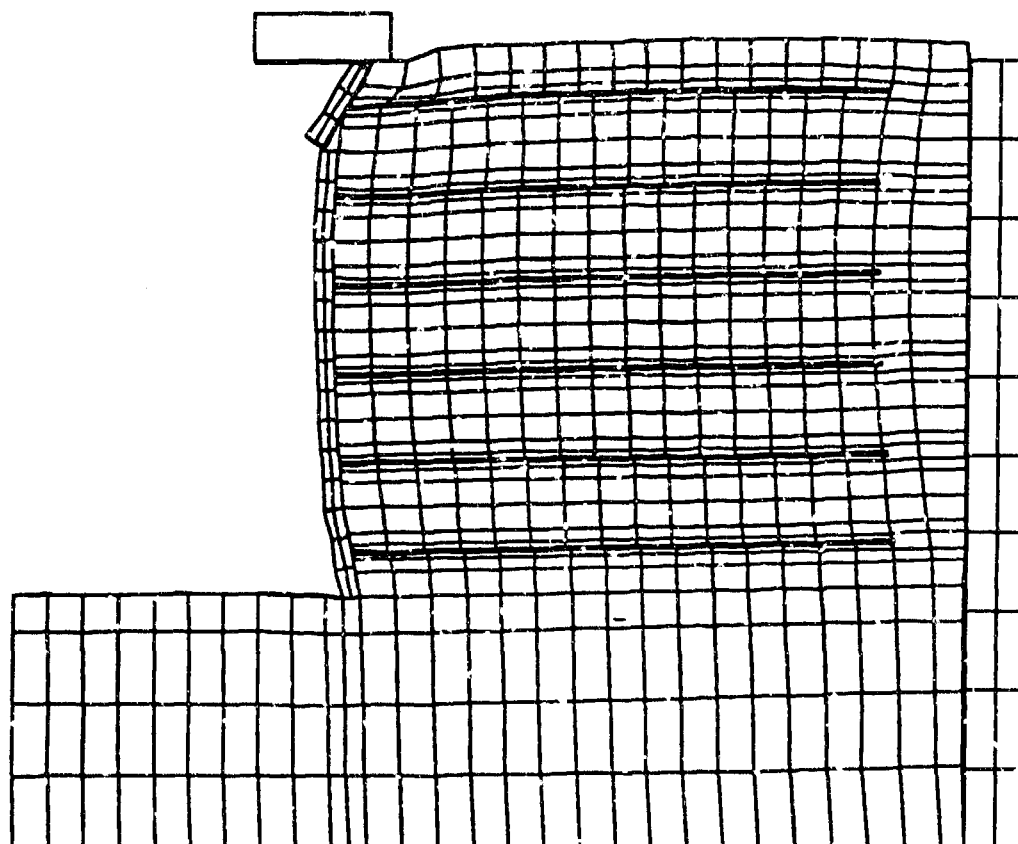
Figure 103. Deformed Shape of Mesh at 0.41 Seconds-
            Analysis PS15 (low interface friction).

159
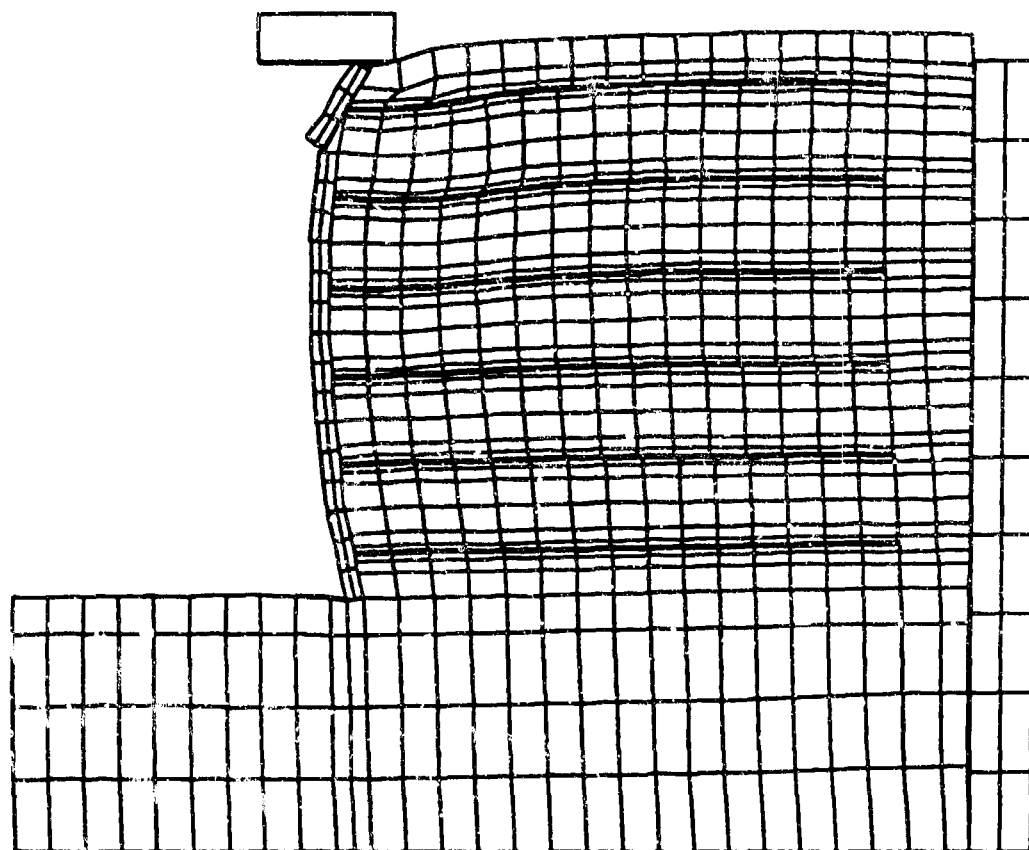
Figure 104. Deformed Shape of Mesh at 0.41 Seconds-
Analysis PS1W (low soil stiffness).

160
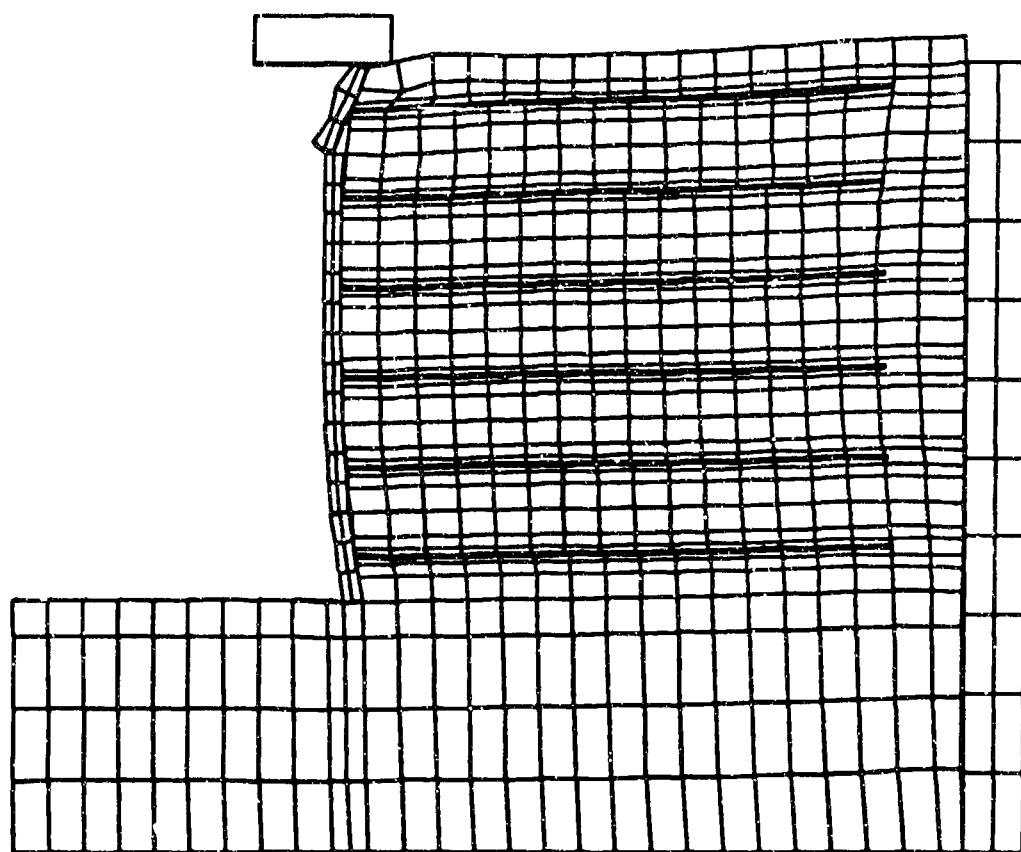
Figure 105. Deformed Shape of Mesh at 0.41 Seconds-
Analysis P1PHI (high soil friction angle).

161
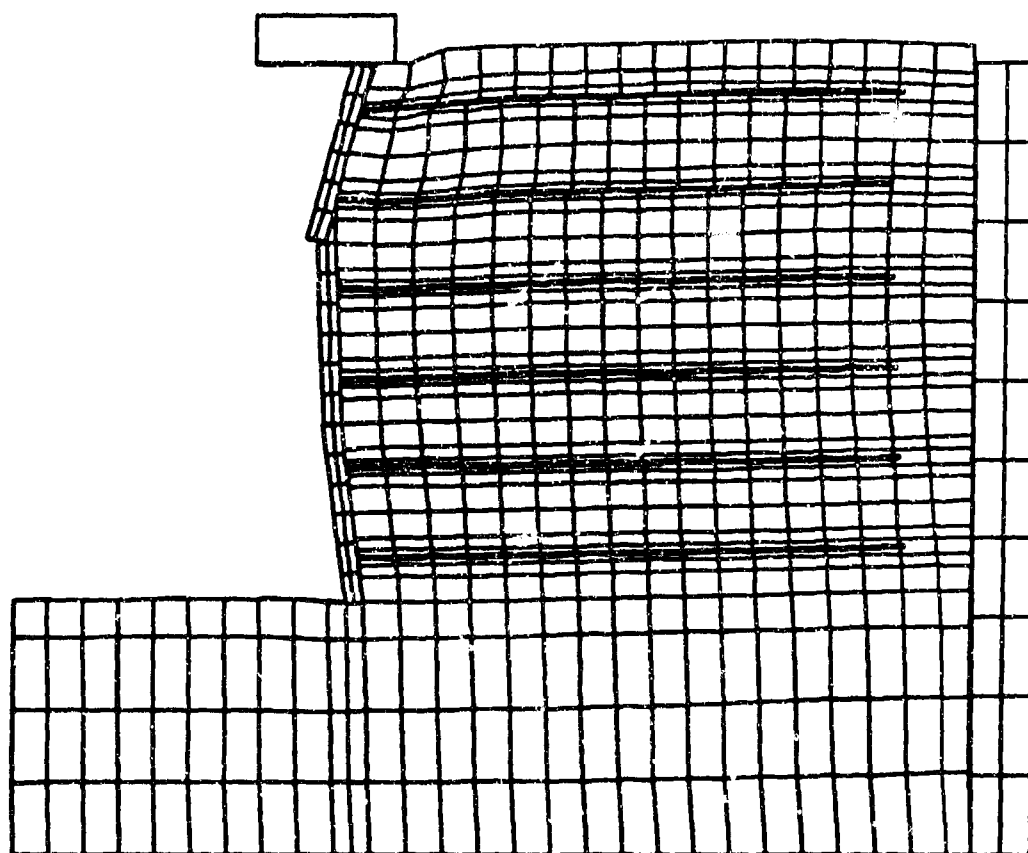
Figure 106. Deformed Shape of Mesh at 0.41 Seconds-
Analysis PS1P (3 facing panels).

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APPENDIX C

PHYSICAL MODELING

A. INTRODUCTION

Appe   C contains a compilation of resistor, pressure gage, and accelerometer data collected and photographs taken throughout the centrifuge testing program. Appendix C is organized as follows:

- acceleration- , voltage-, and pressure-time histories for the centrifuge testing program are presented in Section B.

- model construction sequence, pre-shot and post-shot photographs of the reinforced soil walls for selected tests are presented in Section C.

B. INSTRUMENT DATA

Acceleration-time histories for panels T6, M6, and B6 are presented below for all production tests.   Peak panel accelerations were read directly and blast wave velocities were calculated from these plots. Voltage-time histories for the replicate testing are presented. Peak pressures and blast wave velocities were calculated from these plots. Pressure-time histories for the two pressure gages used in the replicate tests are presented. Peak pressures were read directly and blast wave velocities were calculated from these plots.

163
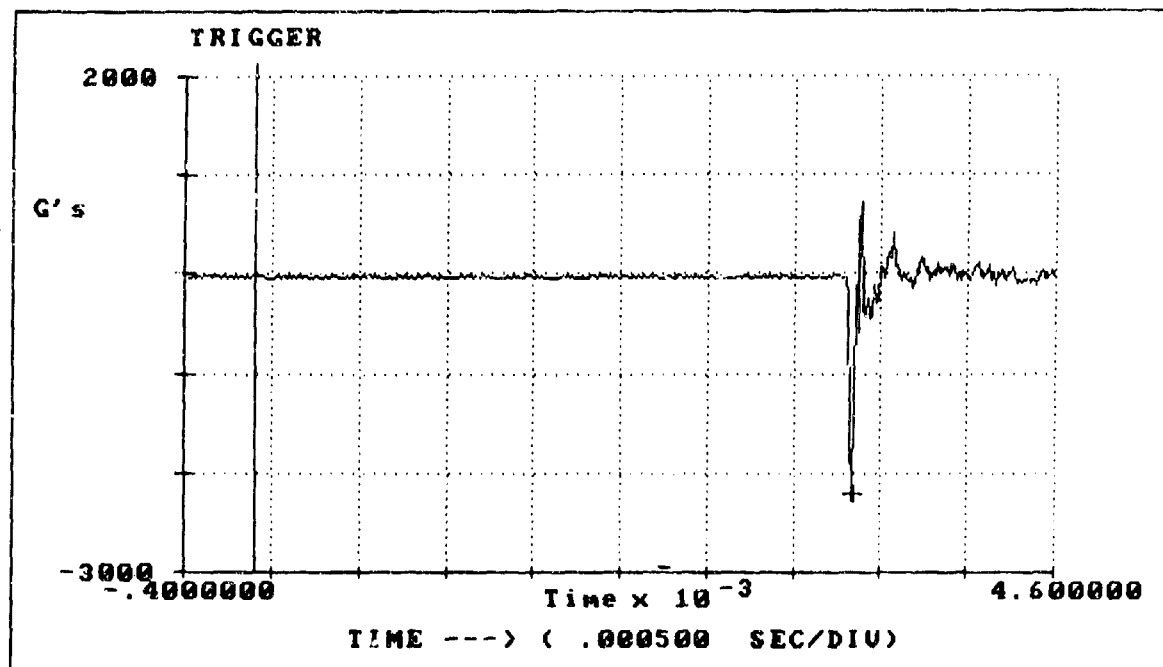
TRIGGER

A-1   TRIGGER OCCURRED   14.561820   SECONDS AFTER START
                              24 APR 92
LEGEND:
   A-1
   ─────────

Time= .003432   G's =-2209.012939

Figure 107.   Acceleration-Time History: Test 1, Panel T6.
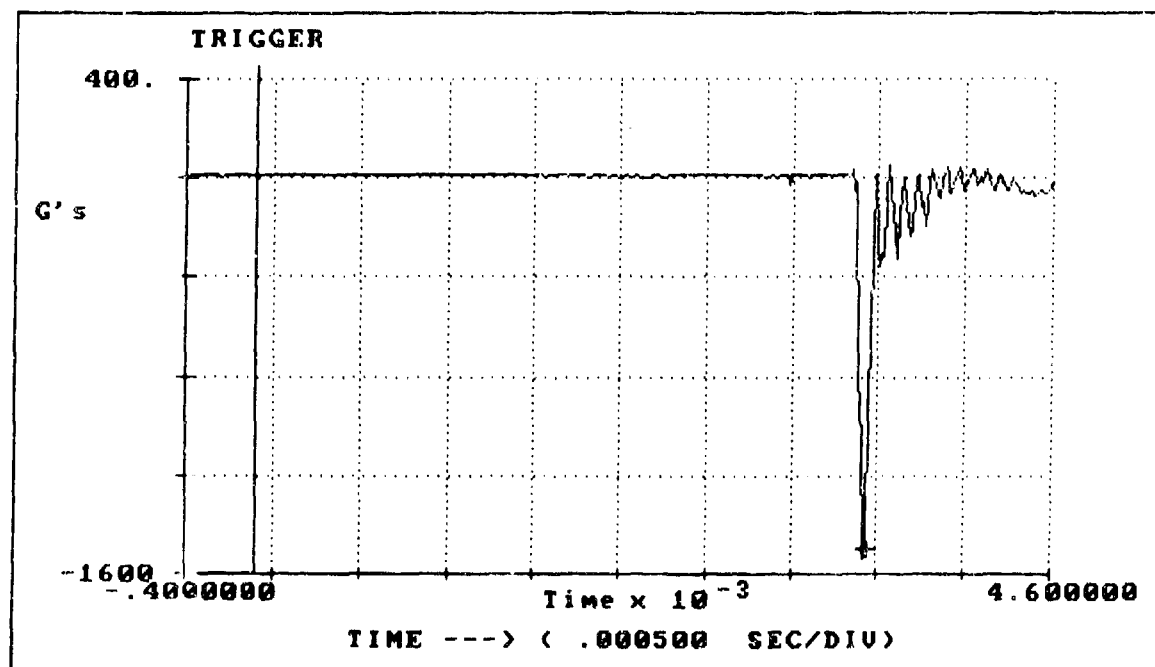
164

Figure 108. Acceleration-Time History: Test 1, Panel M6.

165

TRIGGER OCCURRED 14.561820 SECONDS AFTER START
24 APR 92

A-3

LEGEND:
A-3
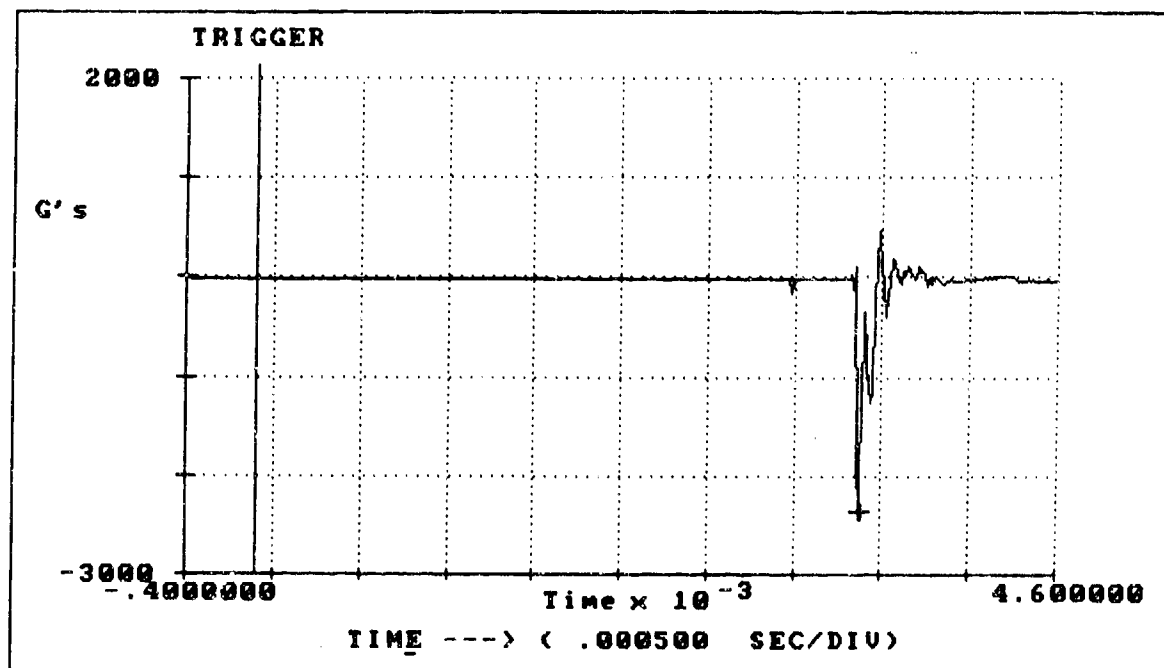
Time= .003460   G's =-2377.840088

Figure 109. Acceleration-Time History: Test 1, Panel B6.

166

TIME ---> (.000500   SEC/DIV)
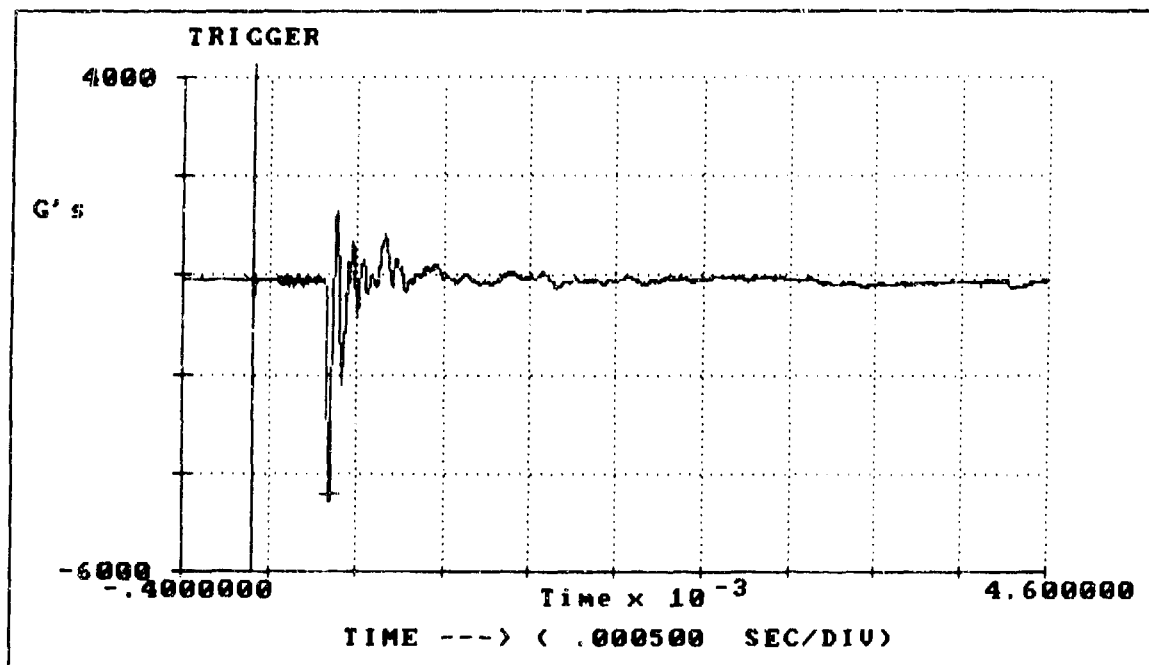
A-1   TRIGGER OCCURRED   18.123056   SECONDS AFTER START
LEGEND: 27 APR 92
    A-1
    _____

Time= .000446   G's =-4405.256836

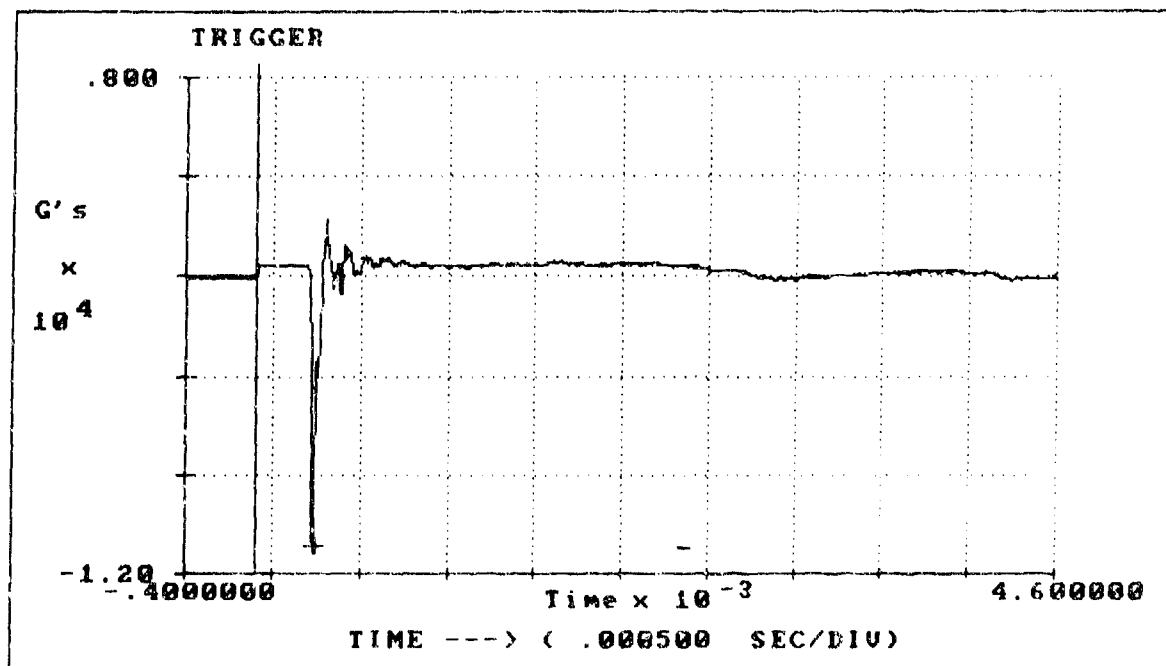Figure 110.   Acceleration-Time History: Test 2, Panel T6.
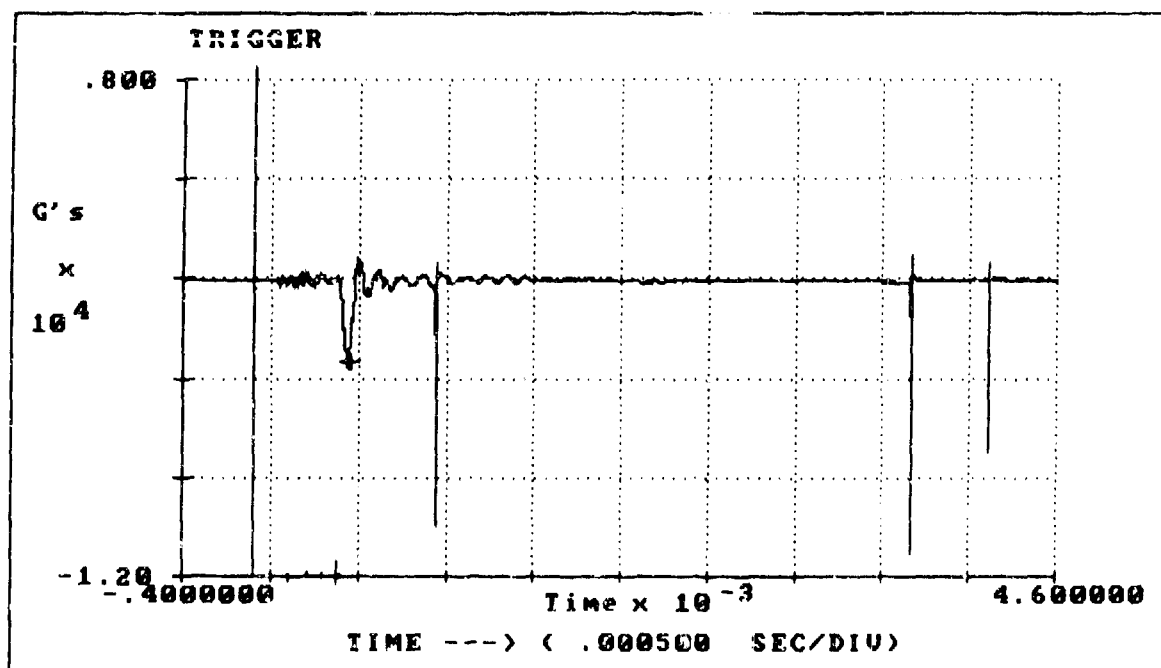
TRIGGER

A-2   TRIGGER OCCURRED 18.123056 SECONDS AFTER START
27 APR 92

LEGEND:
A-2

Time= .006536   G's =-3370.864502

Figure 111.   Acceleration-Time History: Test 2, Panel M6.

168
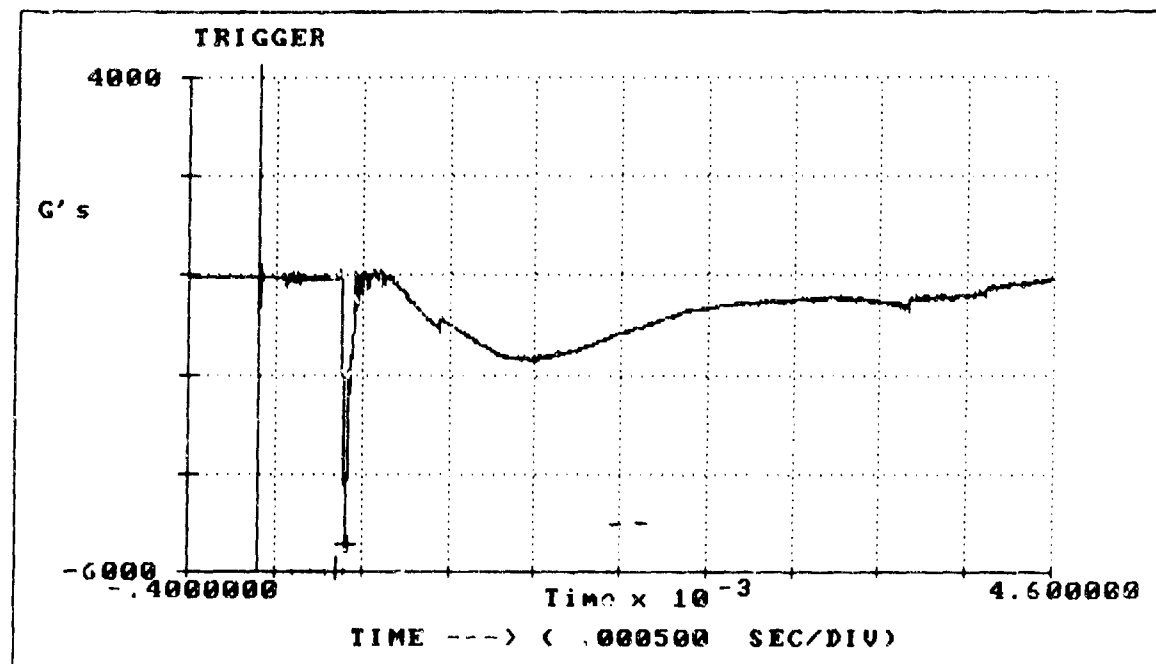
A 3   TRIGGER OCCURRED   13.123056   SECONDS AFTER START
                              27 APR 92
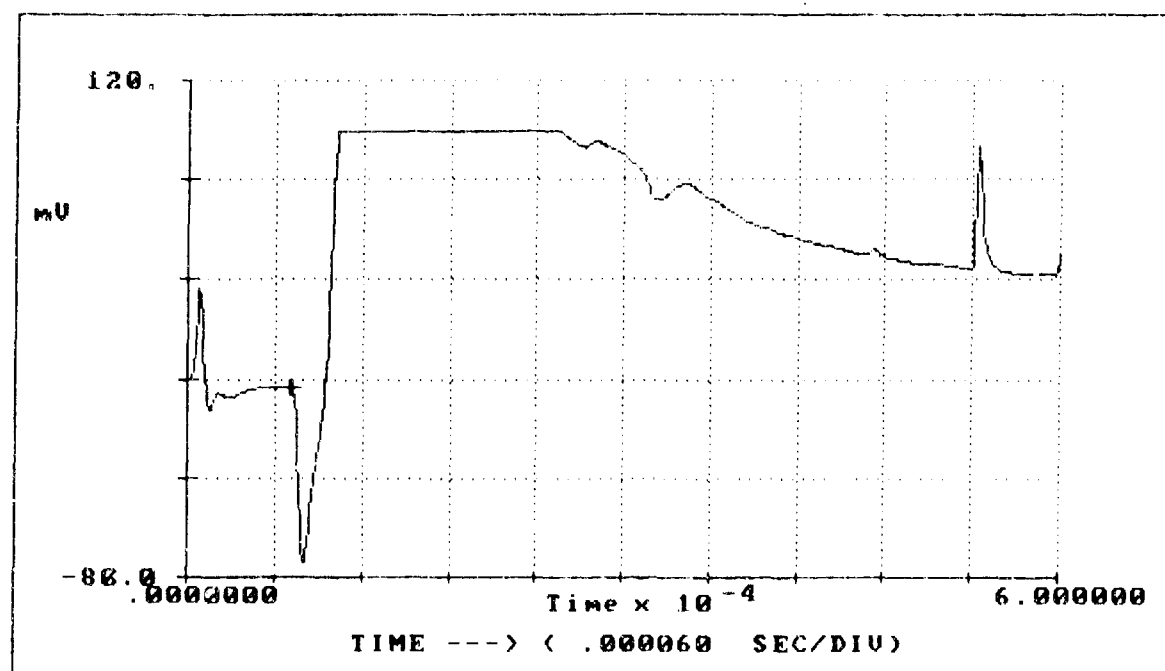
LEGEND:
   A-3

Time= .000502   G's =-5450.197754

Figure 112.   Acceleration-Time History: Test 2, Panel B6.

TRIGGER

5.00

G's

×

10^4 .... FAILED GAGE ....

.000
-.0400000   Time × 10^{-2}   1.210000

TIME ---> (.001250 SEC/DIV)
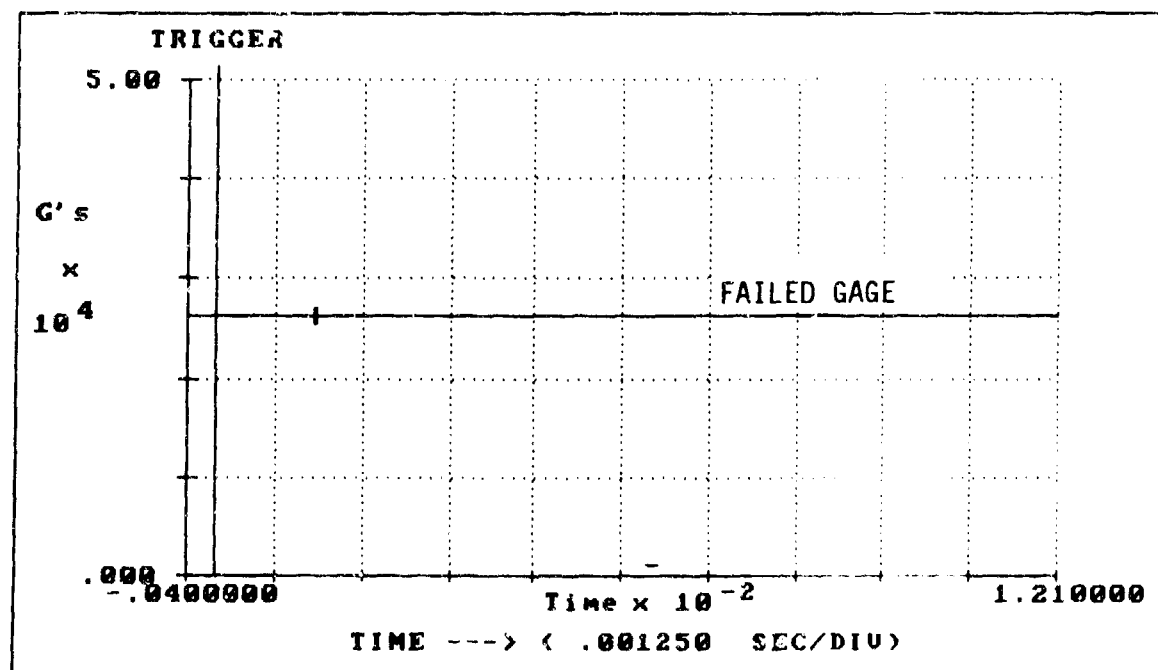
A-1   TRIGGER OCCURRED 15.520102 SECONDS AFTER START
LEGEND: 29 APR 92
    A-1
    _____

Time= .001382   G's = 26150.626953

Figure 113. Acceleration-Time History: Test 3, Panel T6.

170

Figure 114. Acceleration-Time History: Test 3, Panel M6.

171

Figure 115. Acceleration-Time History: Test 3, Panel B6.
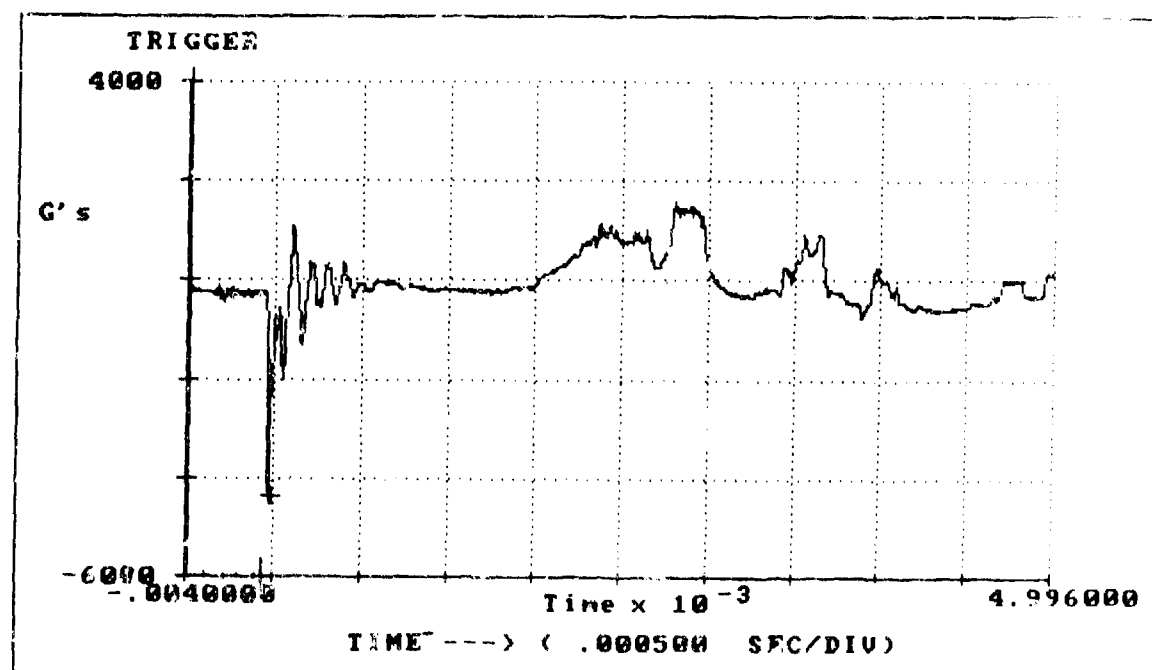
Figure 116. Acceleration-Time History: Test 4, Panel T6.

173

Figure 117. Acceleration-Time History: Test 4, Panel M5.

174

TRIGGER

G's

TIME ---> (.000500 SEC/DIV)
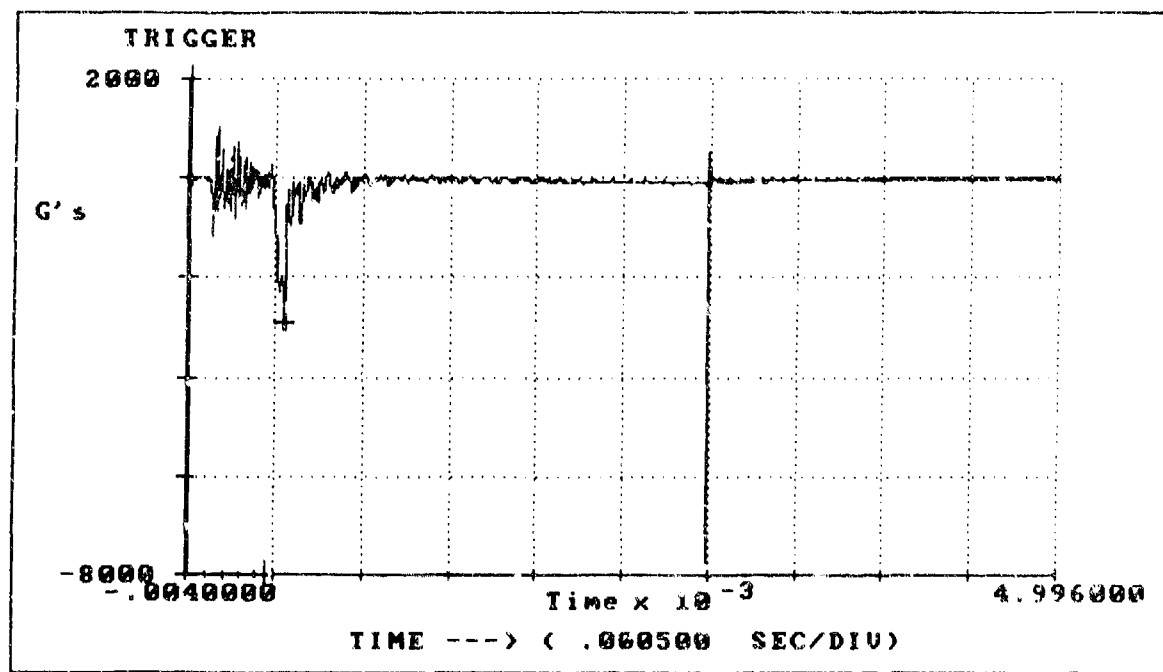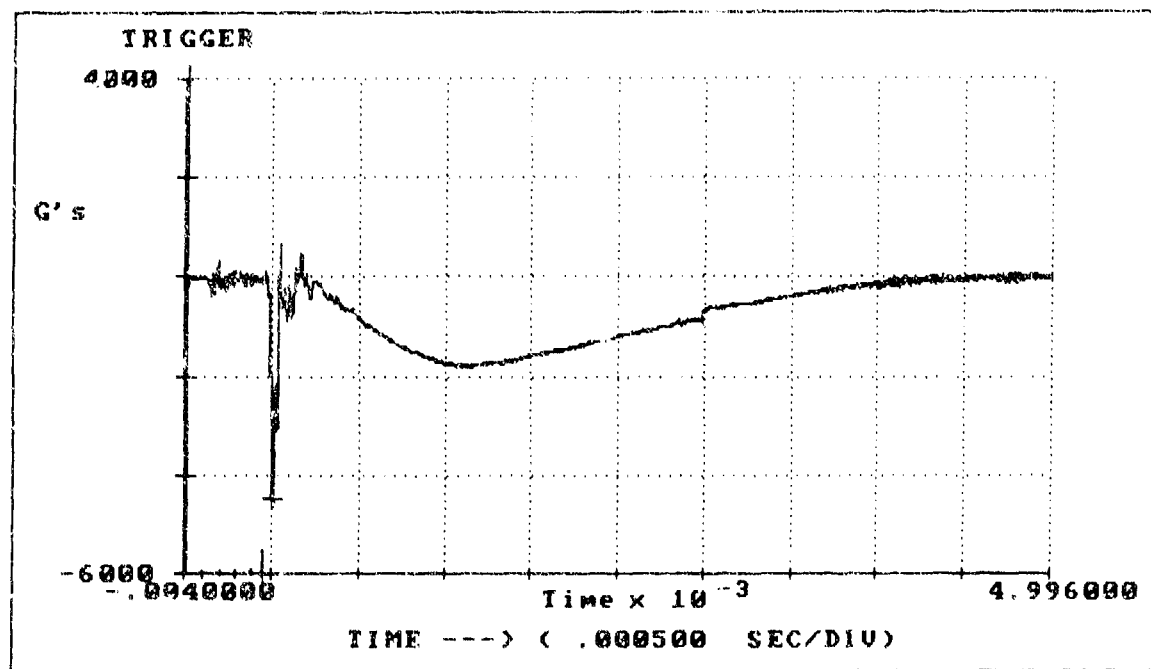
A-3   TRIGGER OCCURRED 18.174528 SECONDS AFTER START

LEGEND: 1 MAY 92
  A-3

Time= .000498   G's =-4484.936035

Figure 118.   Acceleration-Time History: Test 4, Panel B6.

175

Figure 119. Acceleration-Time History: Test 5, Panel T6.

176

Figure 120. Acceleration-Time History: Test 5, Panel M6.
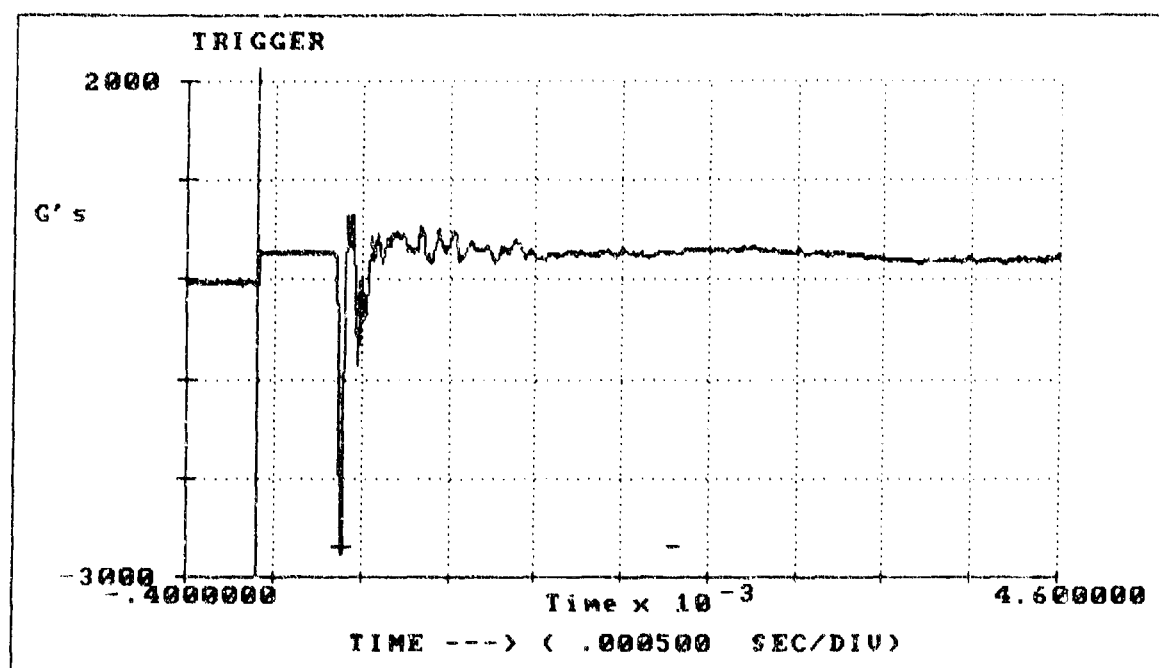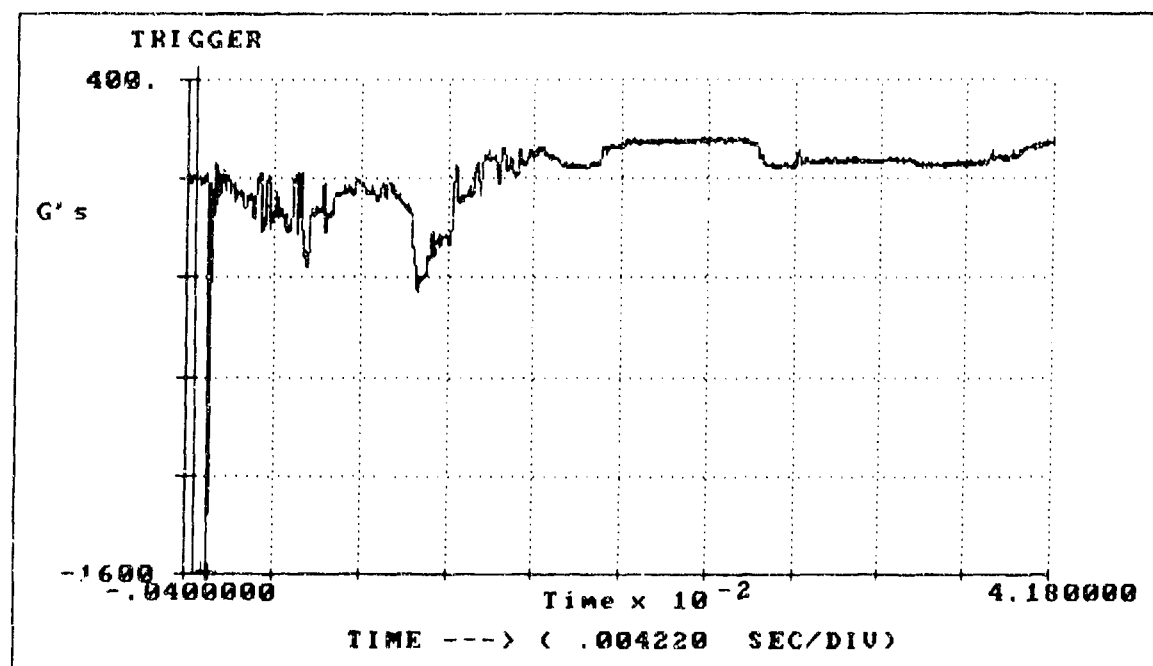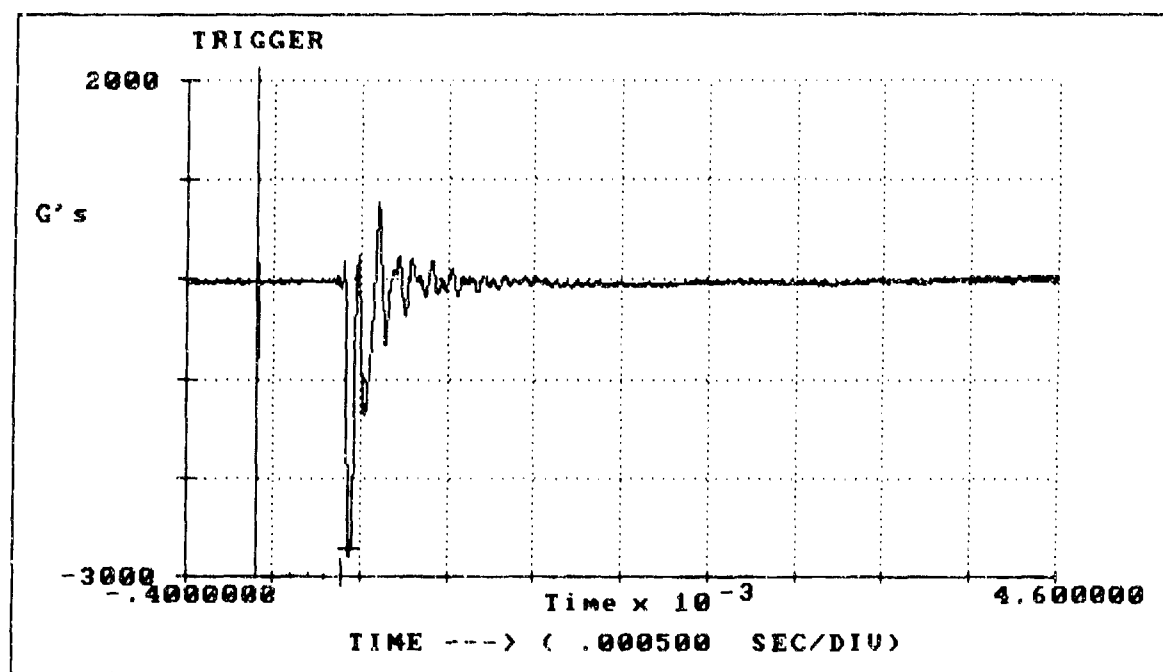
TRIGGER

TRIGGER OCCURRED 15.773801 SECONDS AFTER START
5 MAY 92

A-3

LEGEND:
  A-3

Time= .000532   G's =-2719.213135

Figure 121. Acceleration-Time History: Test 5, Panel B6.

178

Figure 122. Acceleration-Time History: Test 6, Panel T6.

179

Figure 123. Acceleration-Time History: Test 6, Panel M6.

180

TRIGGER

1000

G's

-4000
-.4000000

Time x 10^{-3}   4.600000

TIME ---> (.000500   SEC/DIV)
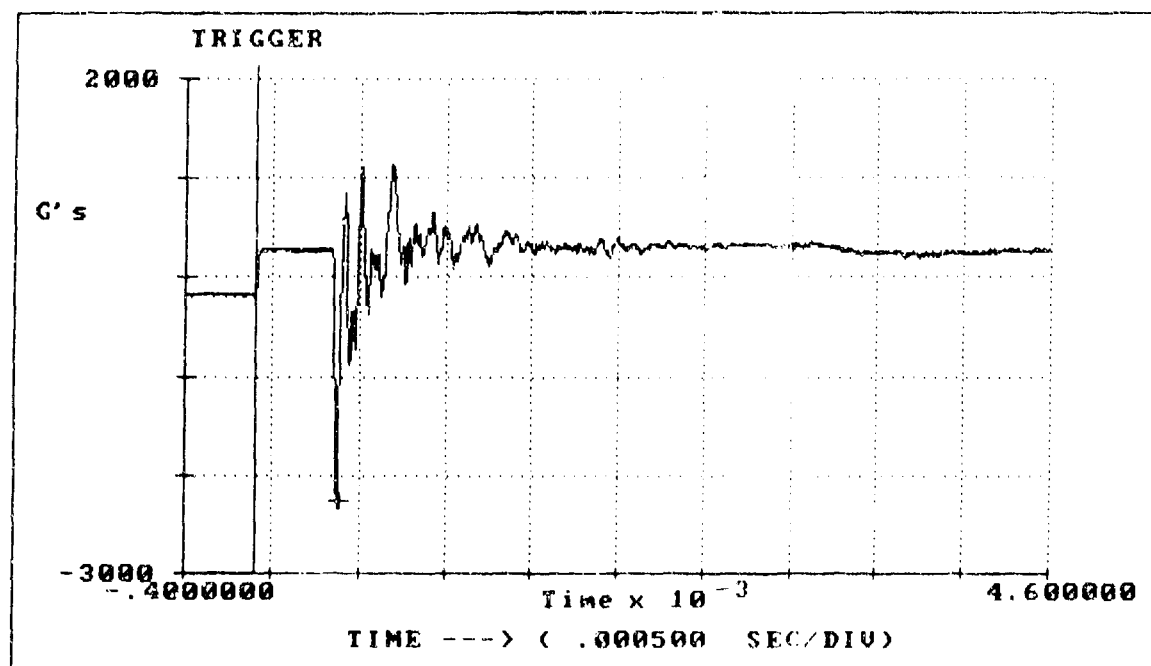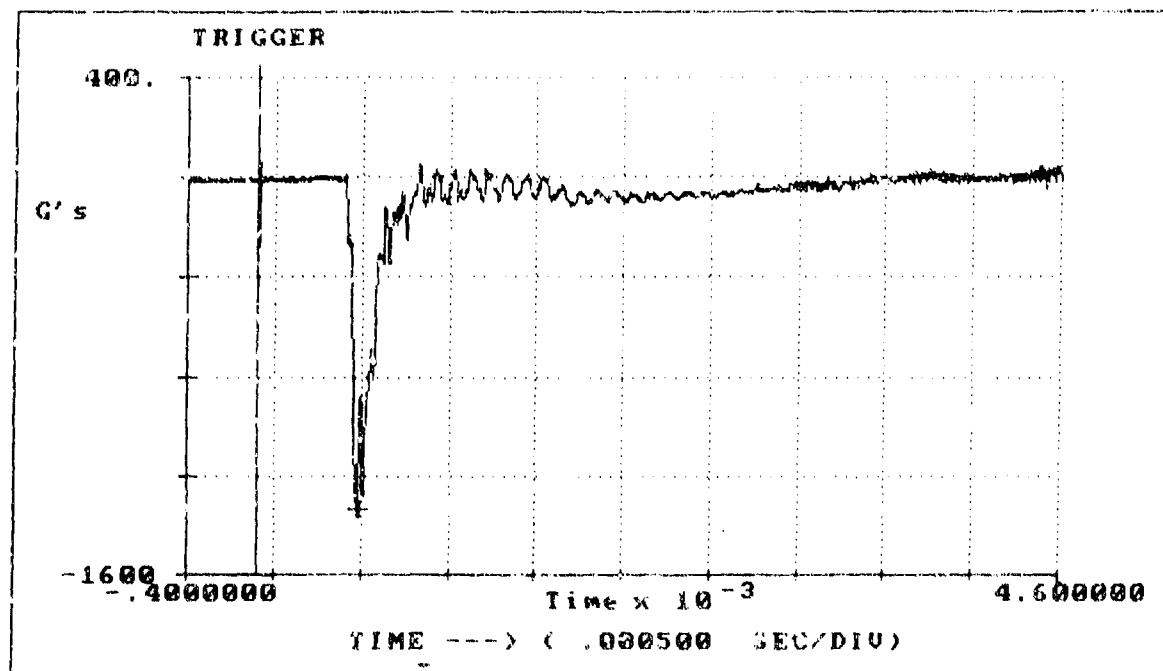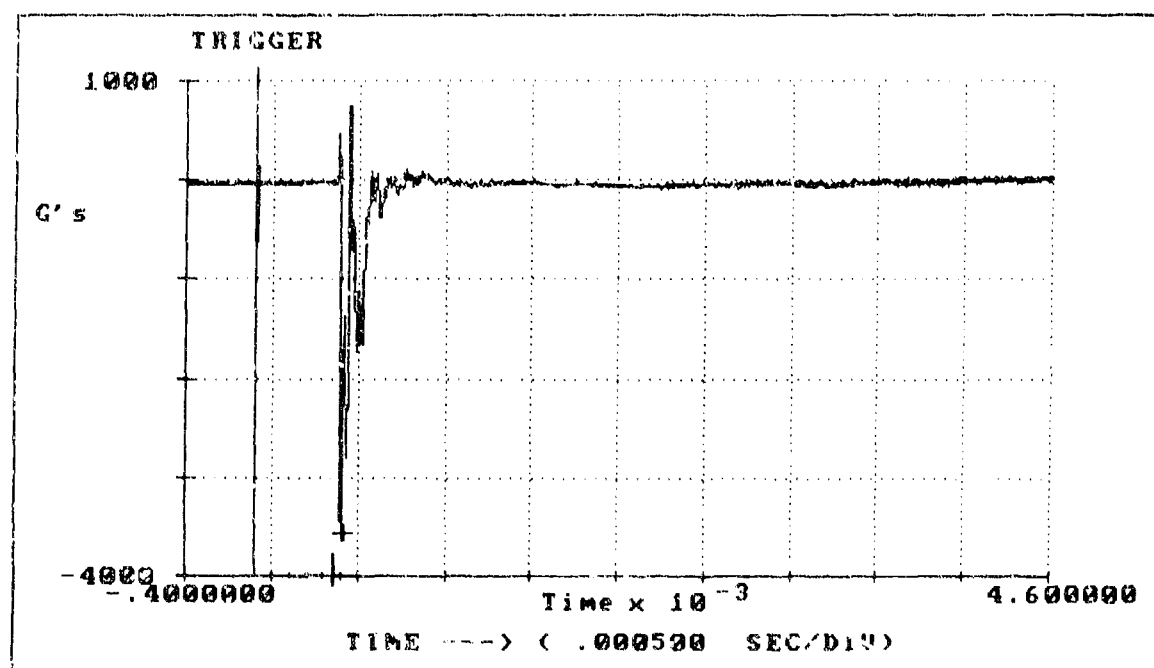
A-3   TRIGGER OCCURRED 15.225677 SECONDS AFTER START
LEGEND: 6 MAY 92
  A-3

Time= .000498   G's =-3578.531738

Figure 124. Acceleration-Time History: Test 6, Panel B6.

TRIGGER

400.	
G's	
-600.	

-.4000000 ... Time x 10⁻³ ... 4.600000

TIME ---> (.000500 SEC/DIV)

A-1   TRIGGER OCCURRED 16.360368 SECONDS AFTER START
LEGEND: 8 MAY 92
   A-1

Time= .001188   G's =-446.910126

Figure 125.   Acceleration Time History: Test 7, Panel T6.
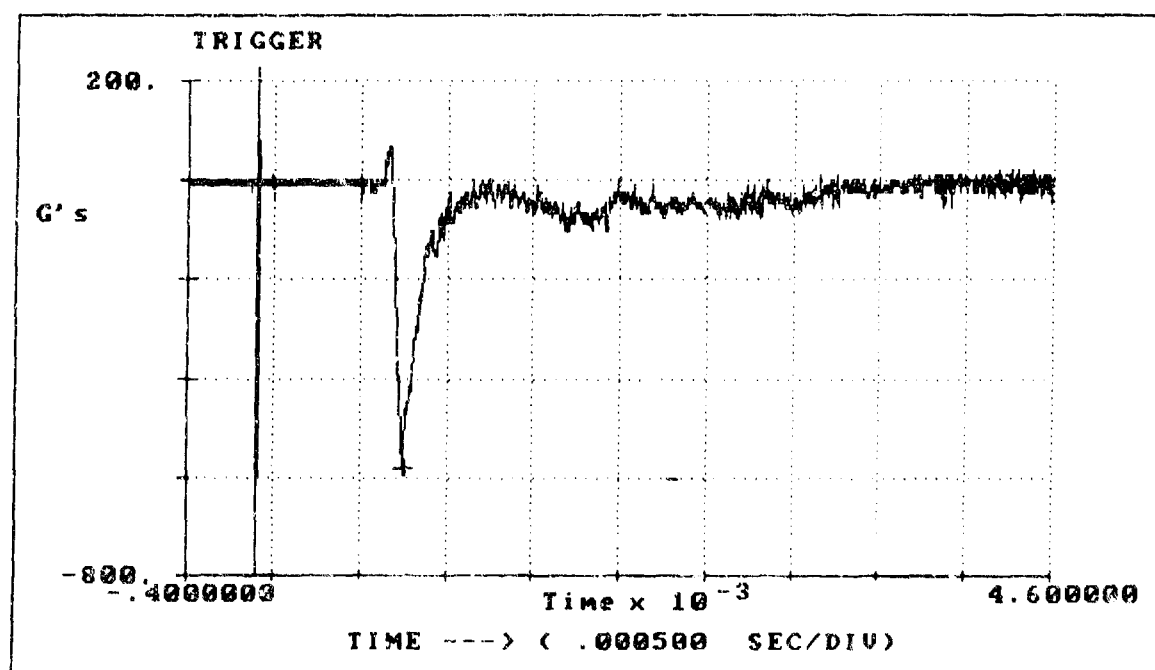
182

Figure 126. Acceleration-Time History: Test 7, Panel M6.

183

TRIGGER

800.

G's

−1200.
−.4000000   Time × 10⁻³   4.600000

TIME ---> (.000500   SEC/DIV)
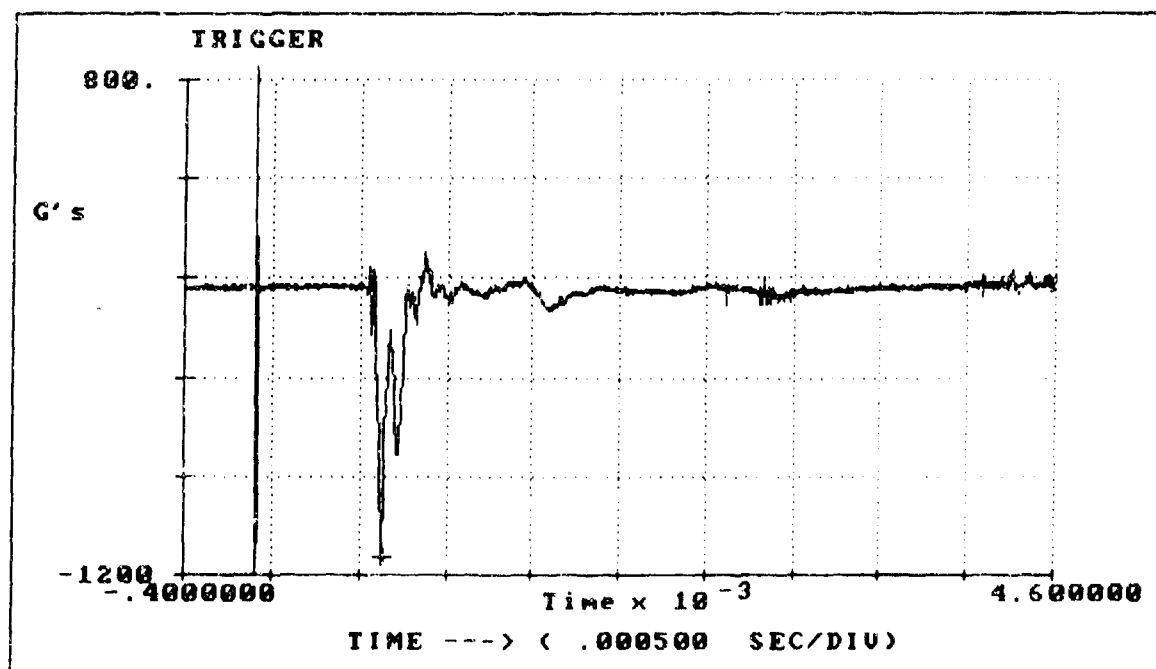
A-3   TRIGGER OCCURRED 16.360368   SECONDS AFTER START
LEGEND: 8 MAY 92
   A-3

Time= .000724   G's =-1130.062622

Figure 127.   Acceleration-Time History: Test 7, Panel B6.

184

A-1   TRIGGER OCCURRED 24.589182 SECONDS AFTER START

LEGEND: 13 MAY 92

A-1
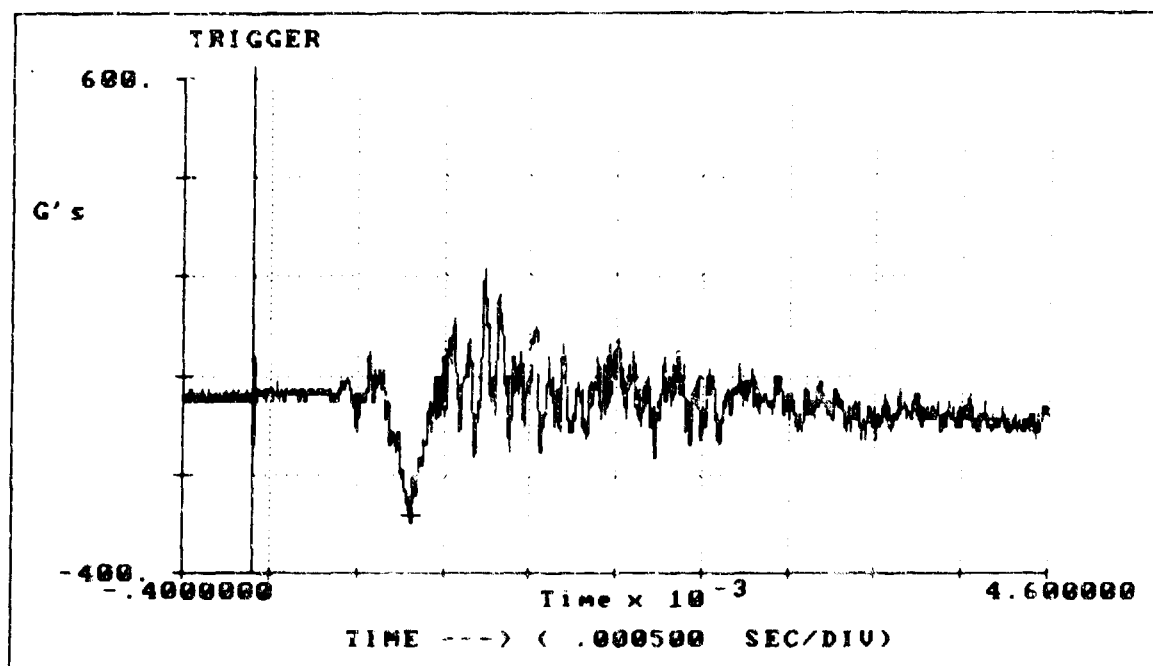
Time= .000982   G's =-280.914948

Figure 128   Acceleration-Time History: Test 8, Panel 16.

185

TRIGGER

5.00

G's

x

10⁴

FAILED GAGE

.000
-.4000000   Time × 10⁻³   4.600000

TIME ---> (.000500 SEC/DIV)
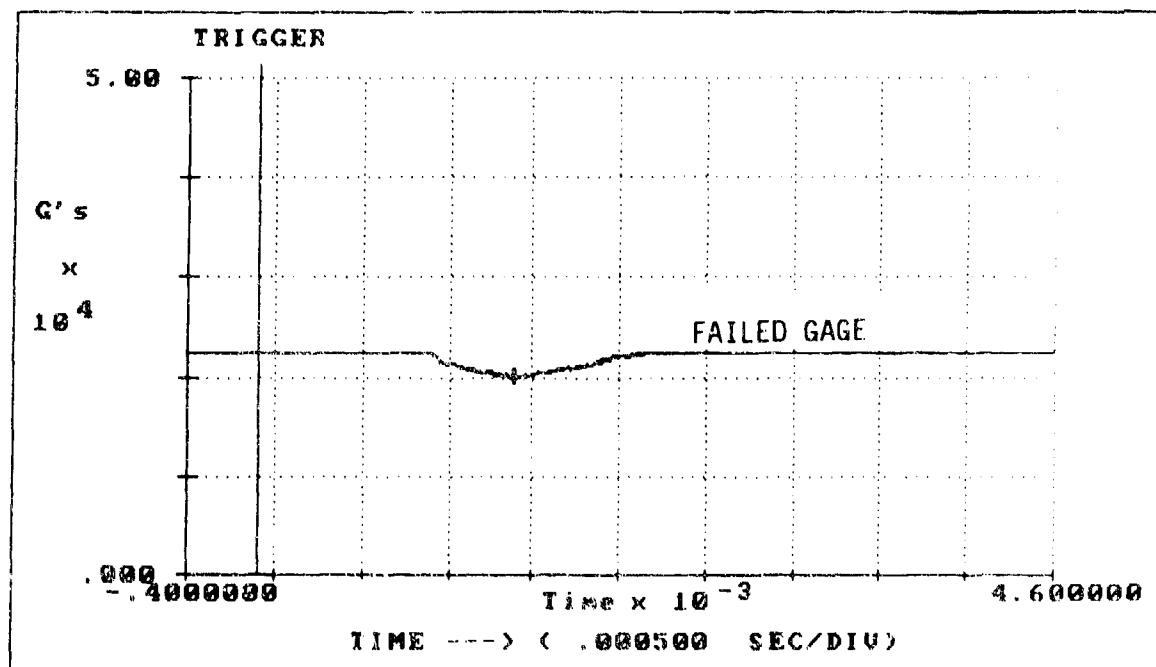
A-2   TRIGGER OCCURRED 24.589182 SECONDS AFTER START
LEGEND: 13 MAY 92
A-2   FAILED BEFORE SHOT

Time= .001400   G's = 20071.466797

Figure 129. Acceleration Time History: Test 8, Panel No.
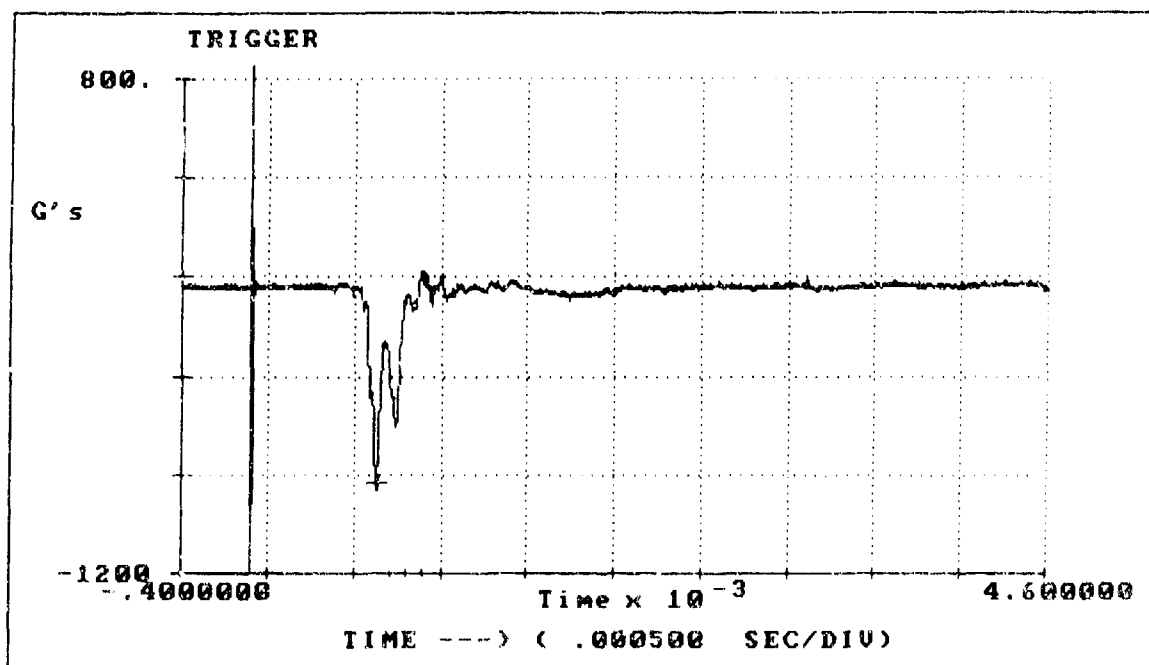
186

Figure 130. Acceleration-Time History: Test 8, Panel B6.

187
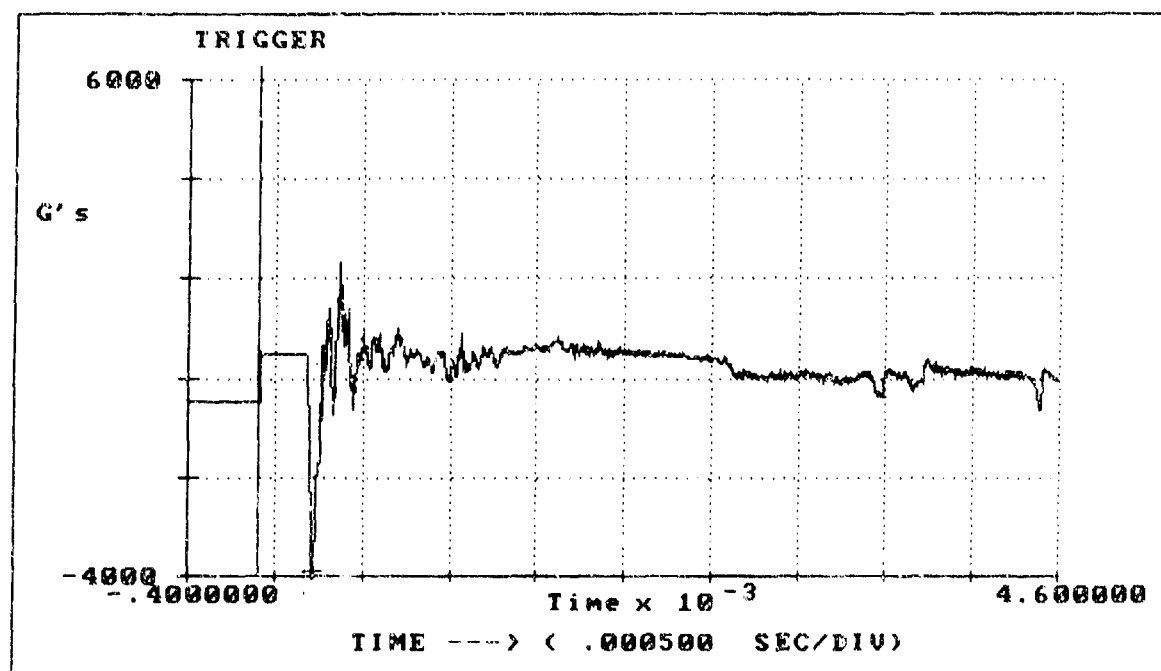
TRIGGER OCCURRED 25.931469 SECONDS AFTER START
15 MAY 92

LEGEND:
A-1

Time= .000312   G's =-3907.271484

Figure 131. Acceleration-Time History: Test 9, Panel T6.
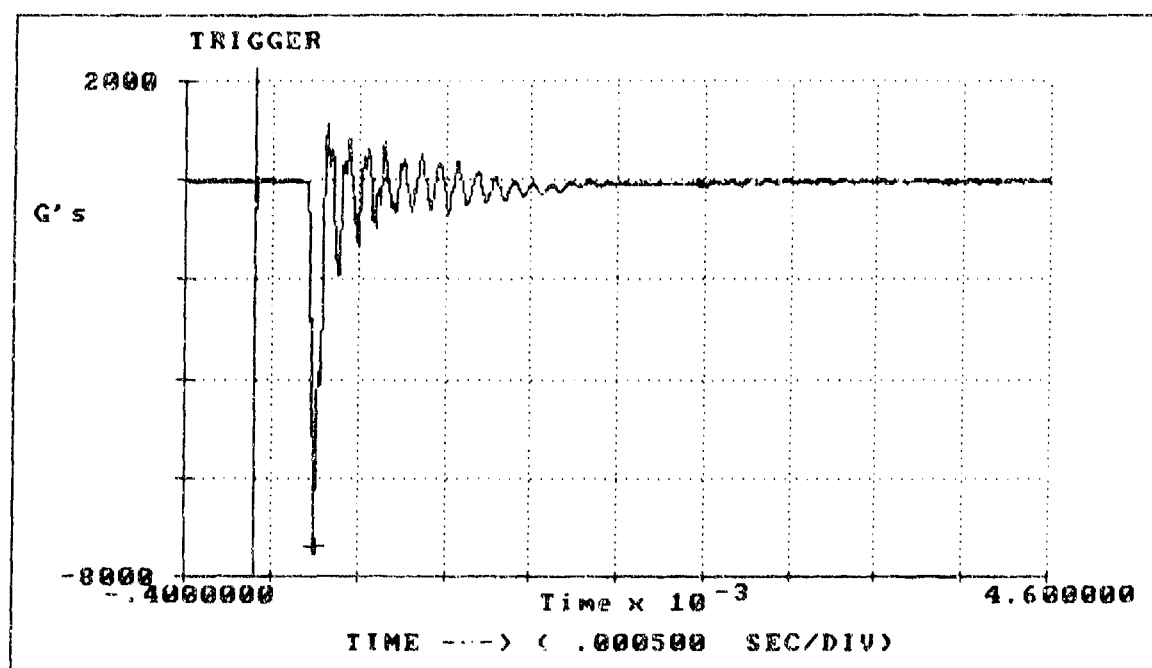
TRIGGER OCCURRED 25.931469 SECONDS AFTER START
15 MAY 92

LEGEND:
A-2

Time= .000344   G's =-7378.569824

Figure 132. Acceleration-Time History: Test 9, Panel M6.

189

Figure 133.   Acceleration-Time History: Test 9, Panel B6.
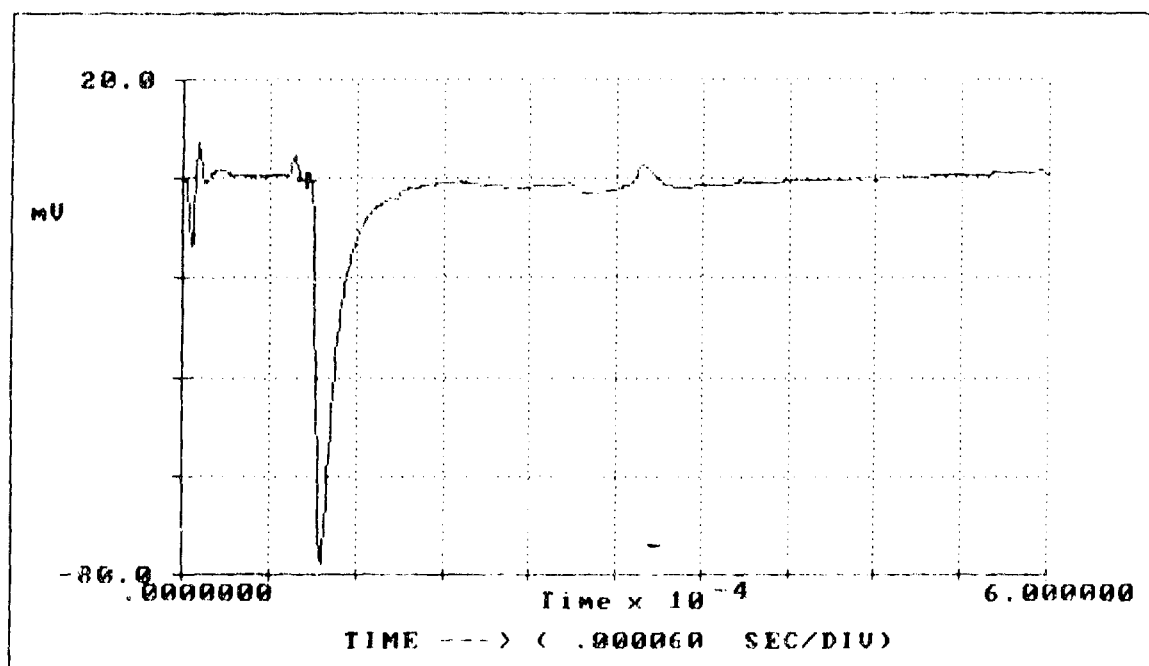
R2   TRIGGER OCCURRED   8.621700   SECONDS AFTER START

LEGEND: 29 JUL   1/8 W @ 2.5"

R2

Time= .000085   mV =-.292969

Figure 134.   Voltage-Time History: Replicate Test- Gage at 2.5 in.

191

```
     120.
      mV


                    Time × 10⁻⁴
   -88.0
    .0000000                              6.000000
         TIME ---> ( .000060   SEC/DIV)
```

R3   TRIGGER OCCURRED 8.621700 SECONDS AFTER START
                          29 JUL 1/8 W @ 3"

LEGEND:
    R3

Time= .000070   mV =-3.222656

Figure 135.   Voltage-Time History: Replicate Test- Gage at 3.0 in.

192
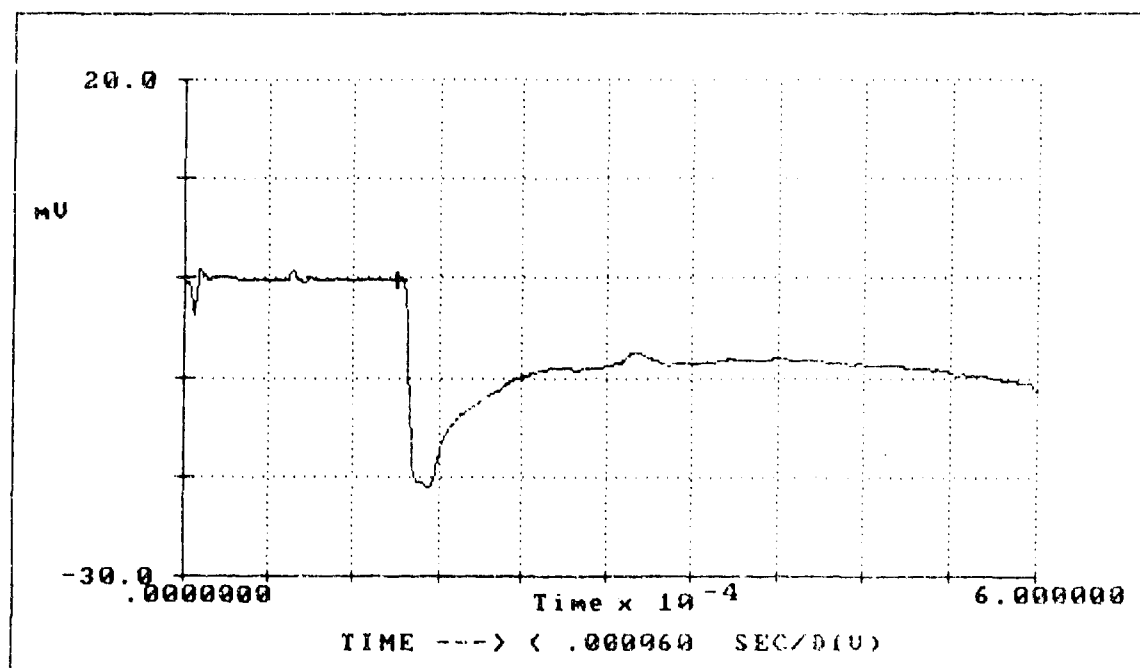
R4   TRIGGER OCCURRED 8.621700   SECONDS AFTER START
LEGEND: 29 JUL 1/8 W @ 5 "
   R4
   _____

Time= .000150   mV =-.073242

Figure 136.   Voltage-Time History: Replicate Test- Gage at 4.5 in.

193

Figure 137. Voltage-Time History: Replicate Test- Gage at 5.0 in.

194
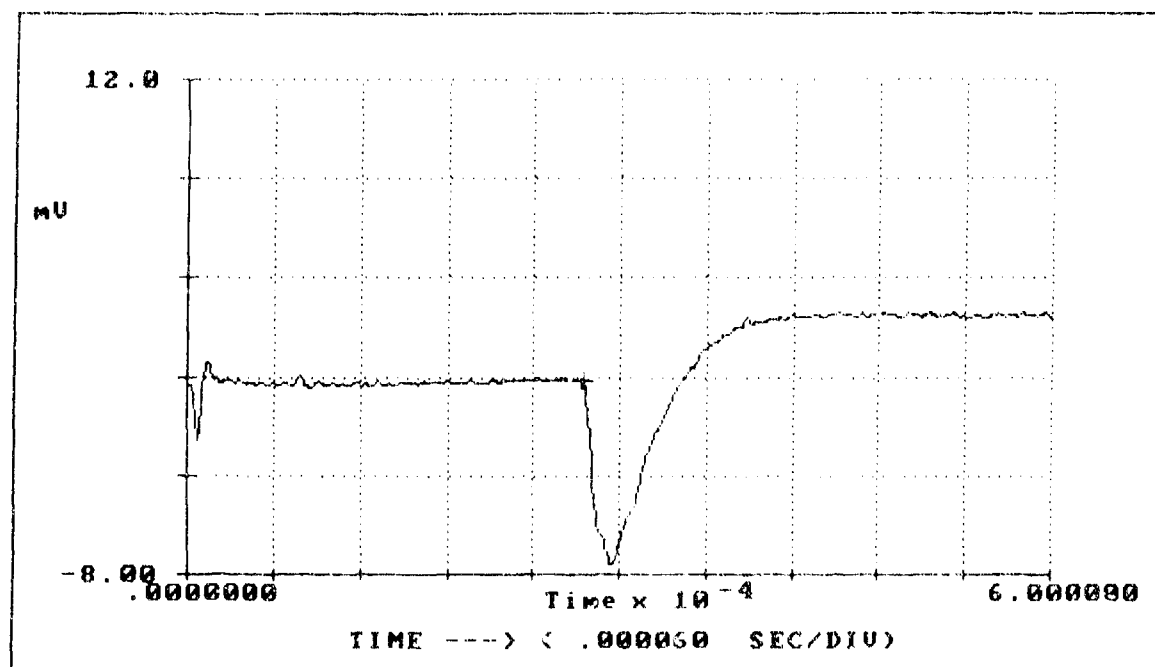
R5   TRIGGER OCCURRED 8.621768 SECONDS AFTER START
LEGEND: 29 JUL 1/8 W @ 7"
  R5

Time= .000273   mV = -.136719

Figure 138.   Voltage-Time History: Replicate Test- Gage at 7.0 in.

195

Figure 139.   Voltage-Time History: Replicate Test- Gage at 8.0 in.

Figure 140. Voltage-Time History: Replicate Test- Gage at 8.5 in.

197
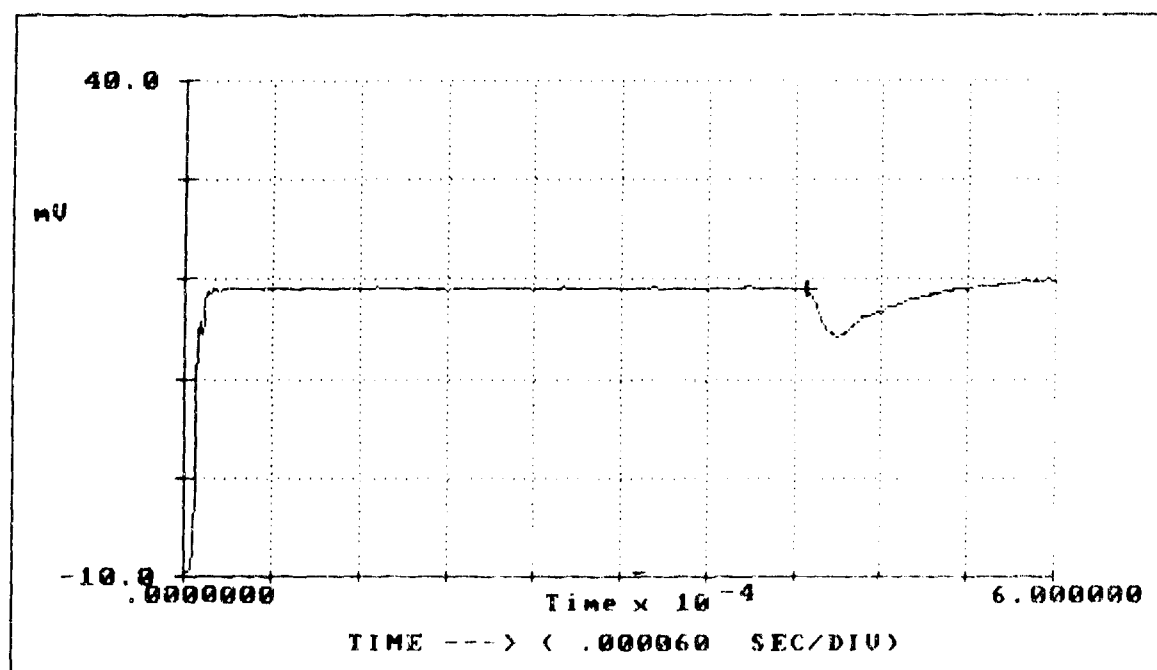
R6   TRIGGER OCCURRED 8.621700 SECONDS AFTER START

LEGEND: 29 JUL 1/8 W @ 9"
  R6

Time= .009428   mV = 19.023438

Figure 141. Voltage-Time History: Replicate Test Gage at 9.0 in.
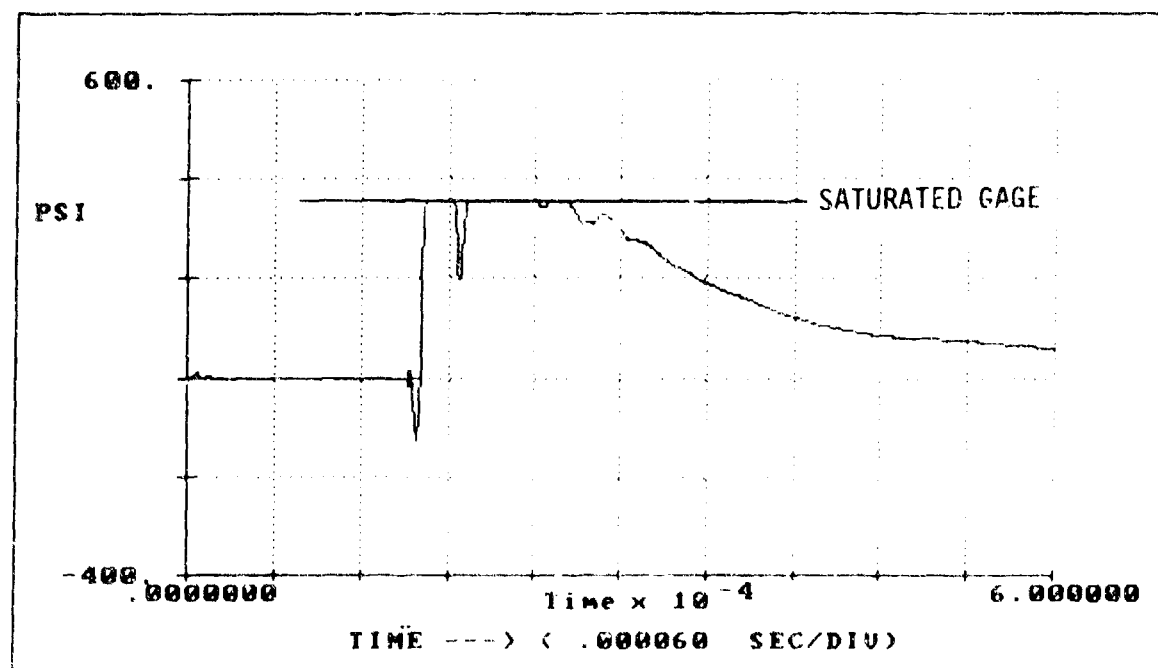
198

Time= .000152   PSI =-.345197

Figure 142.   Pressure-Time History: Replicate Test Gage at 4.0 in.

400.

PSI

-100.
.1000000   Time × 10⁻⁴   6.100000
                TIME ---> (.000060   SEC/DIV)
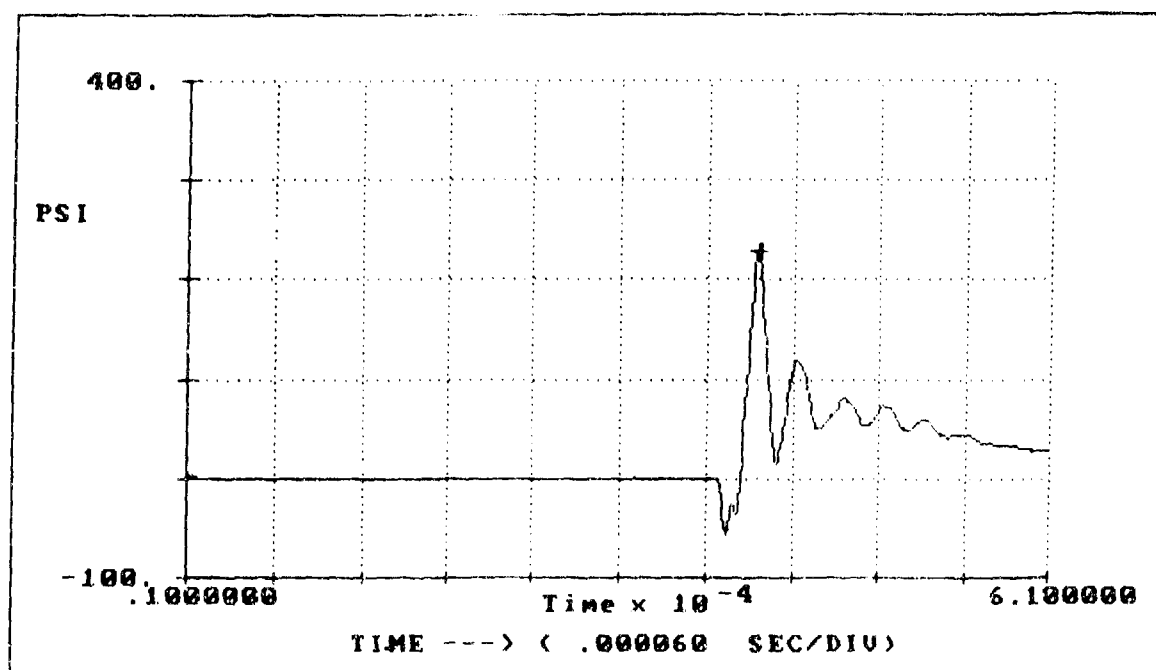
FF2   TRIGGER OCCURRED 9.729735 SECONDS AFTER START
LEGEND: PRESSURE GAGE @ 8.5
    FF2

Time= .000405   PSI = 229.210999

Figure 143. Pressure-Time History: Replicate Test Gage at 8.5 in.

200

B: PHOTOGRAPHS

Figures 144 - 162 present the construction sequence for preparation of a reinforced soil wall. Figures 163 - 169 present post-shot deformations of select walls.

201
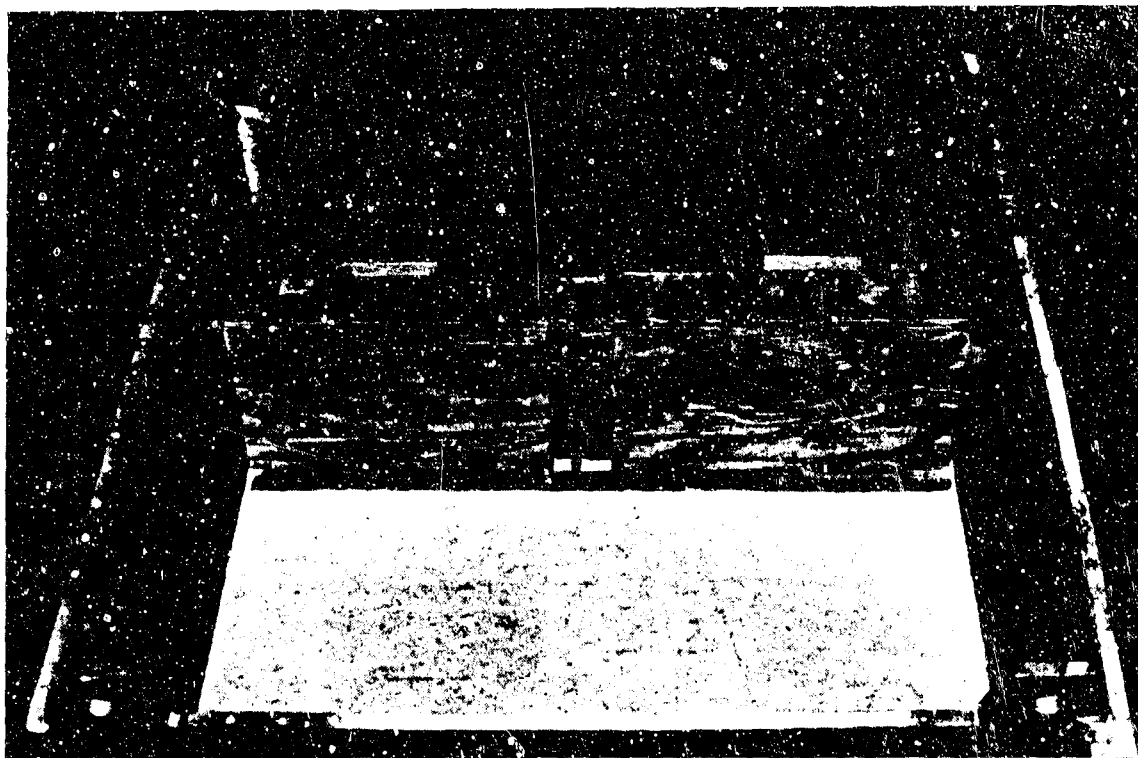
Figure 144. Pluviated Base and Bracing Block
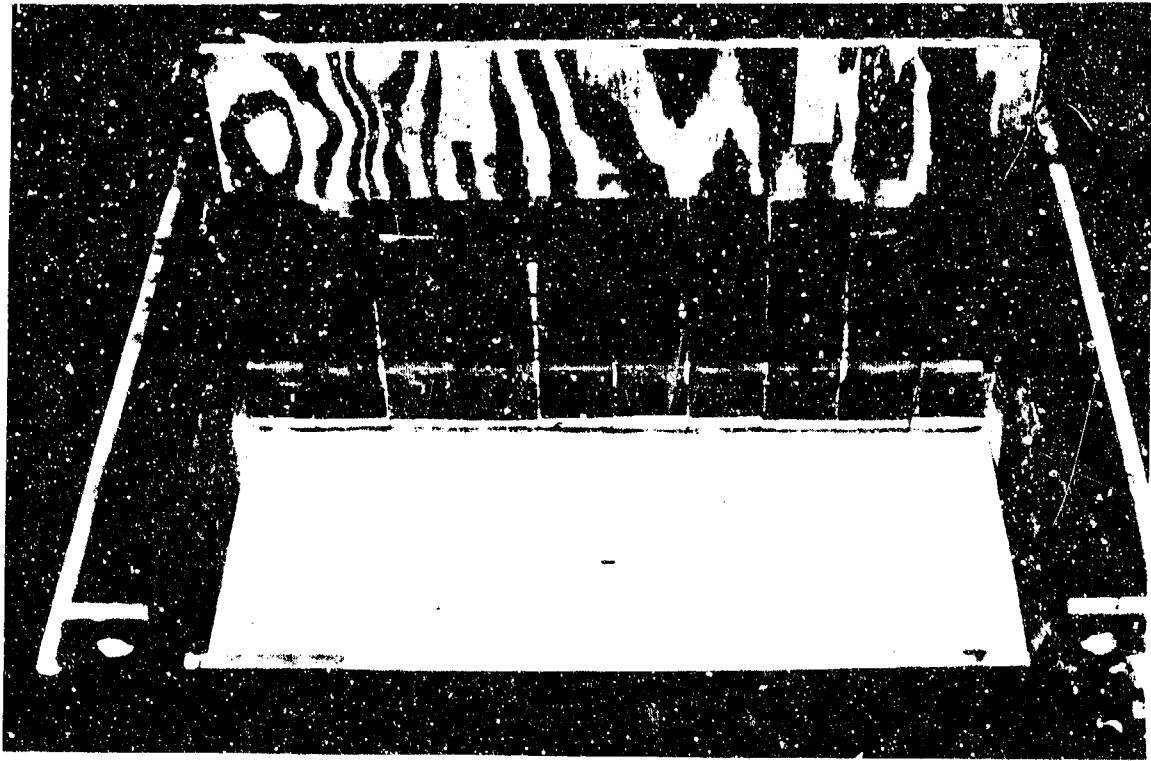
Figure 145. First Course of Facing Panels

Figure 146. First Level of Reinforcement
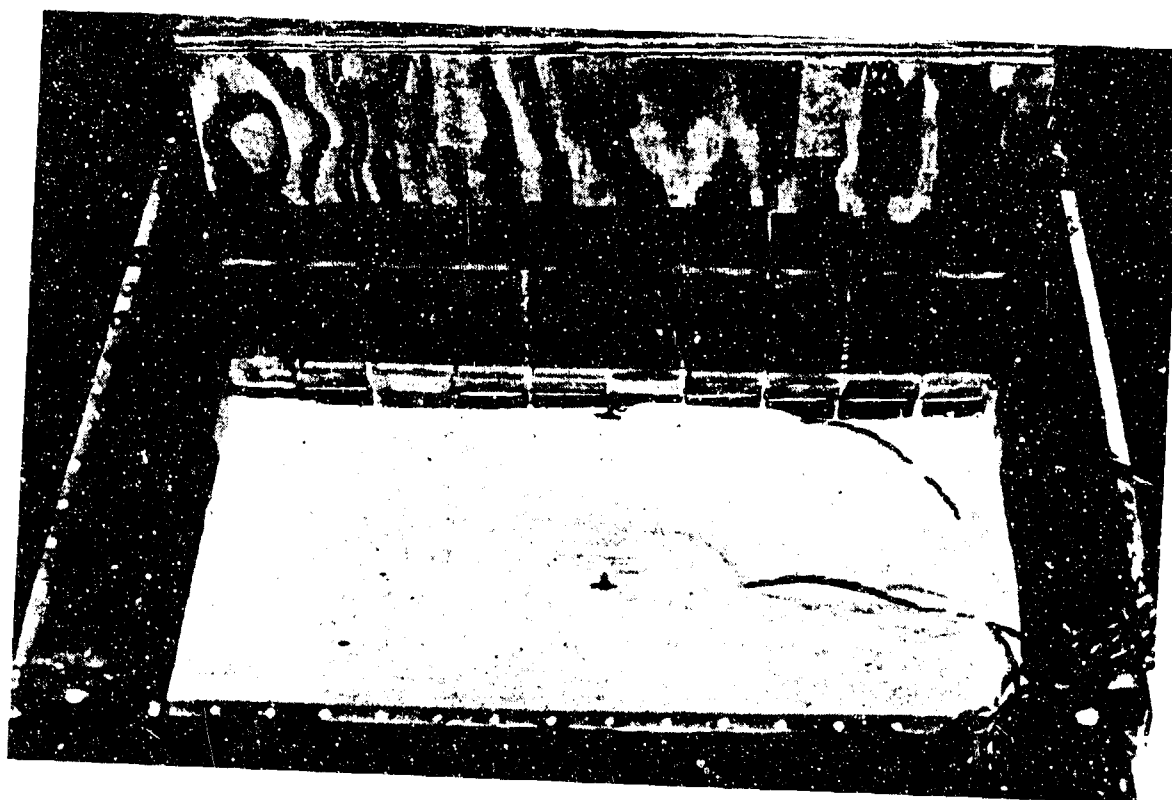
Figure 147. First Level of Instrumentation
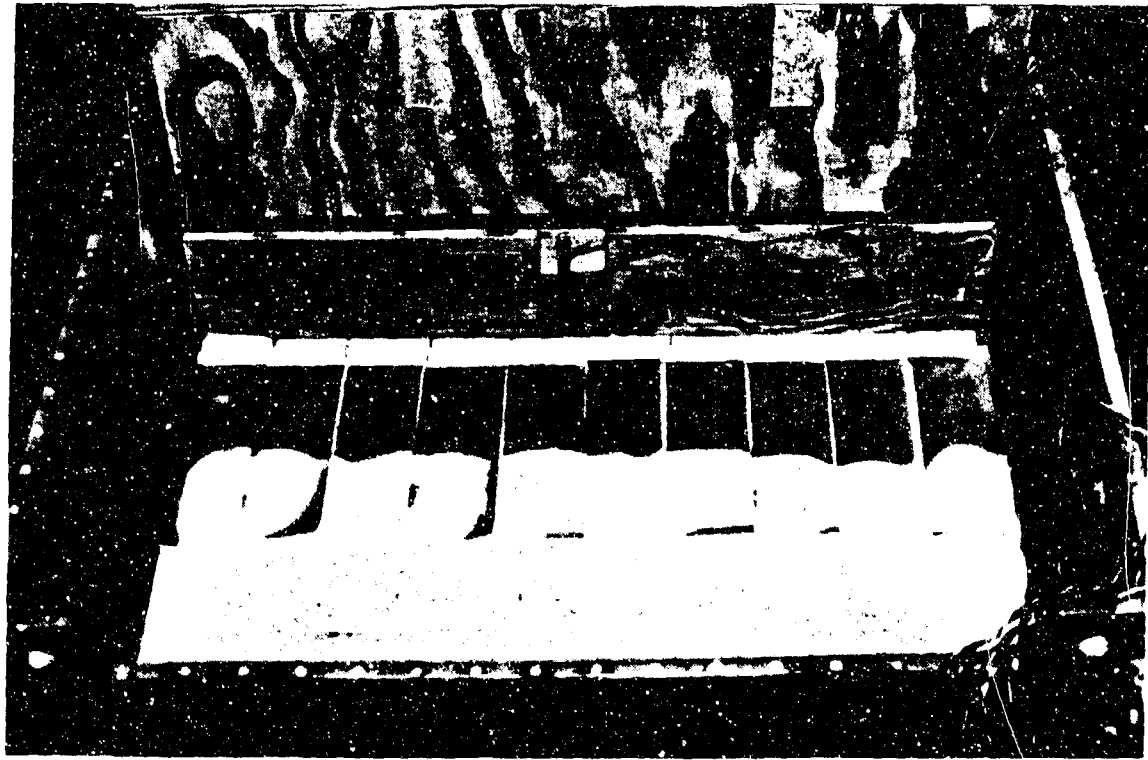
Figure 148. Second Level of Reinforcement
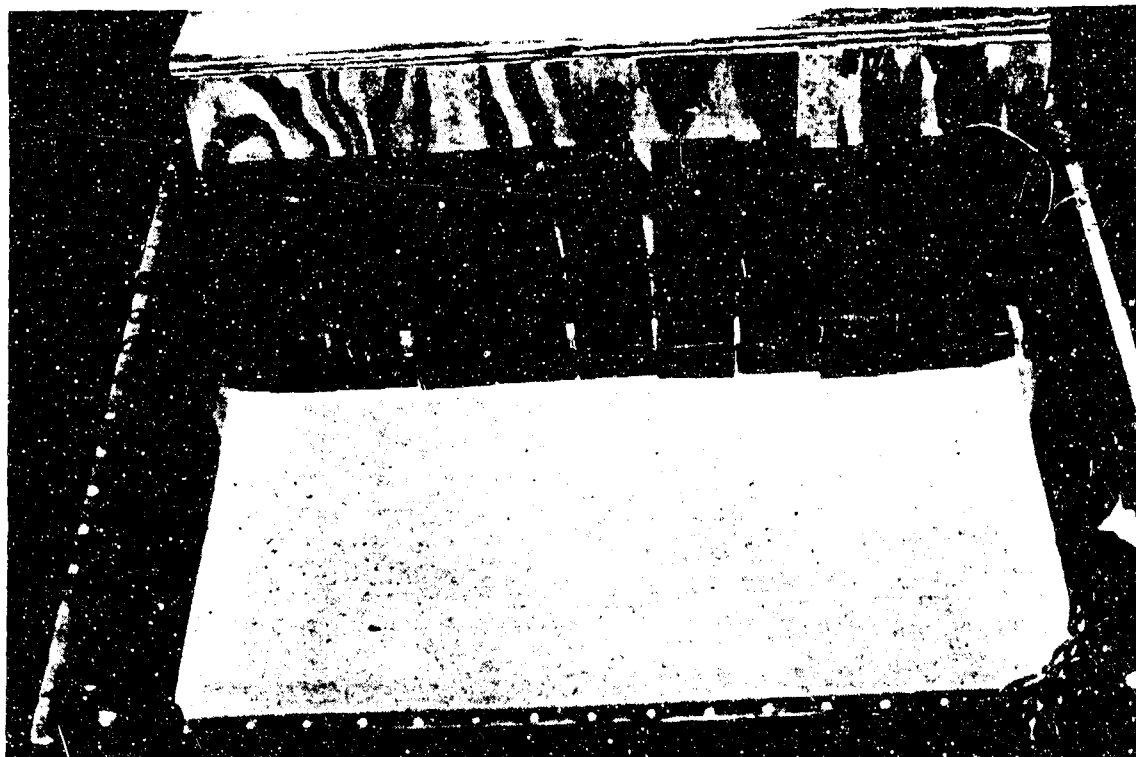
Figure 149.   Second Course of Facing Panels
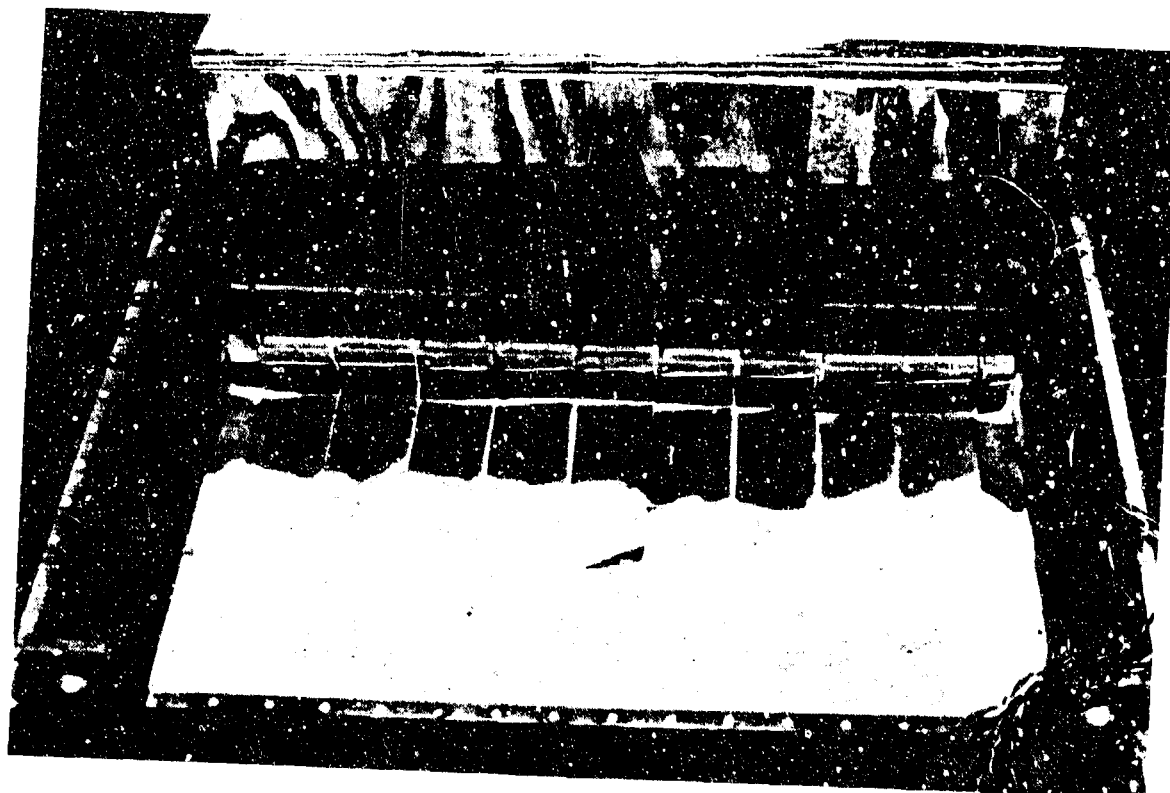
Figure 150. Third level of Reinforcement

208
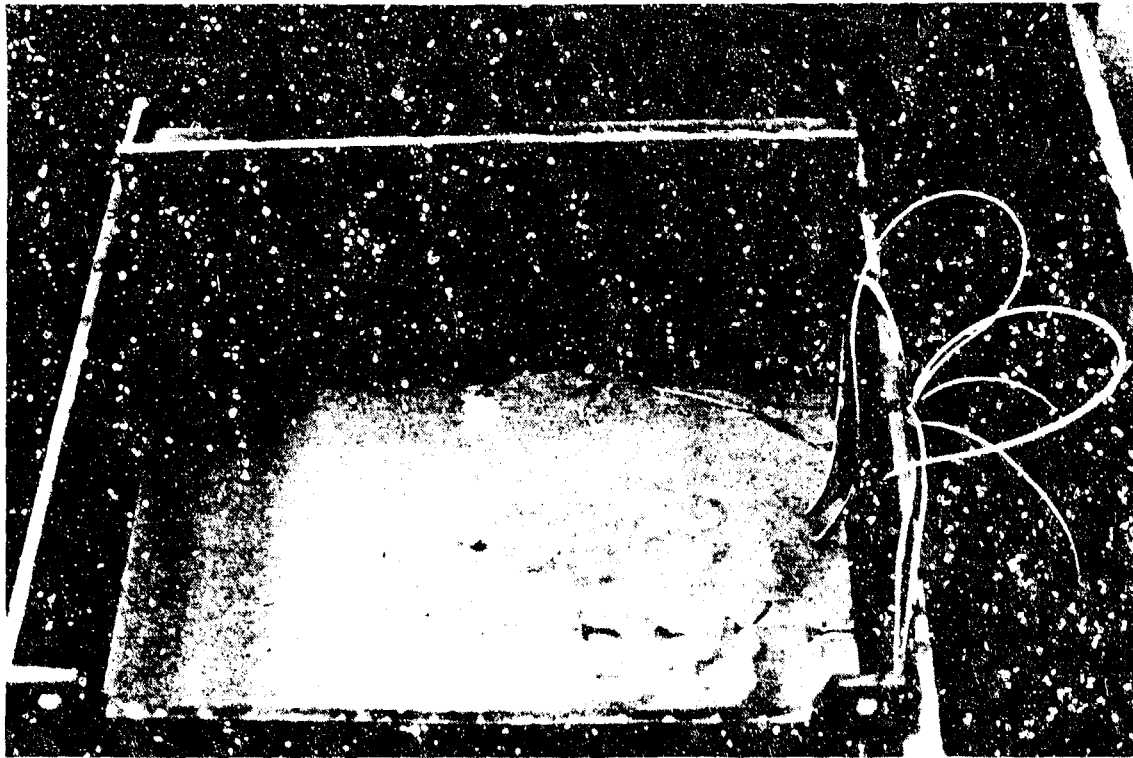
Figure 151. Second Level of Instrumentation

209
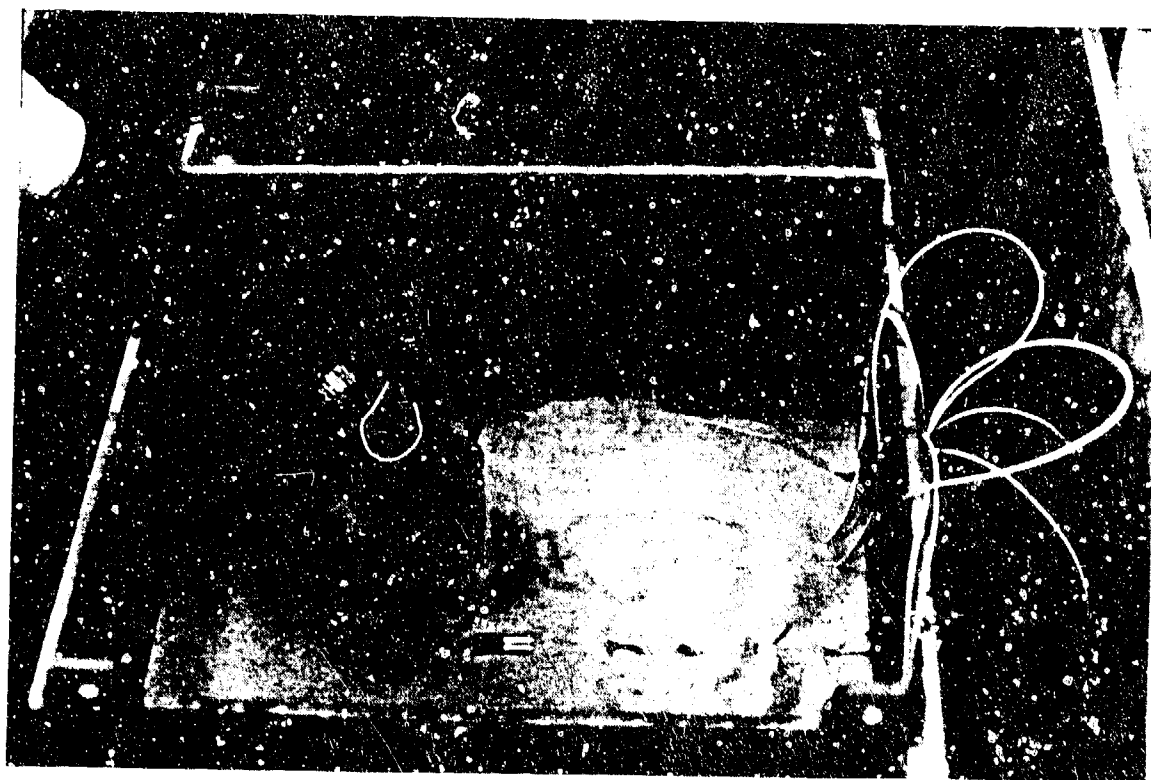
Figure 152. Detonater Placement

210
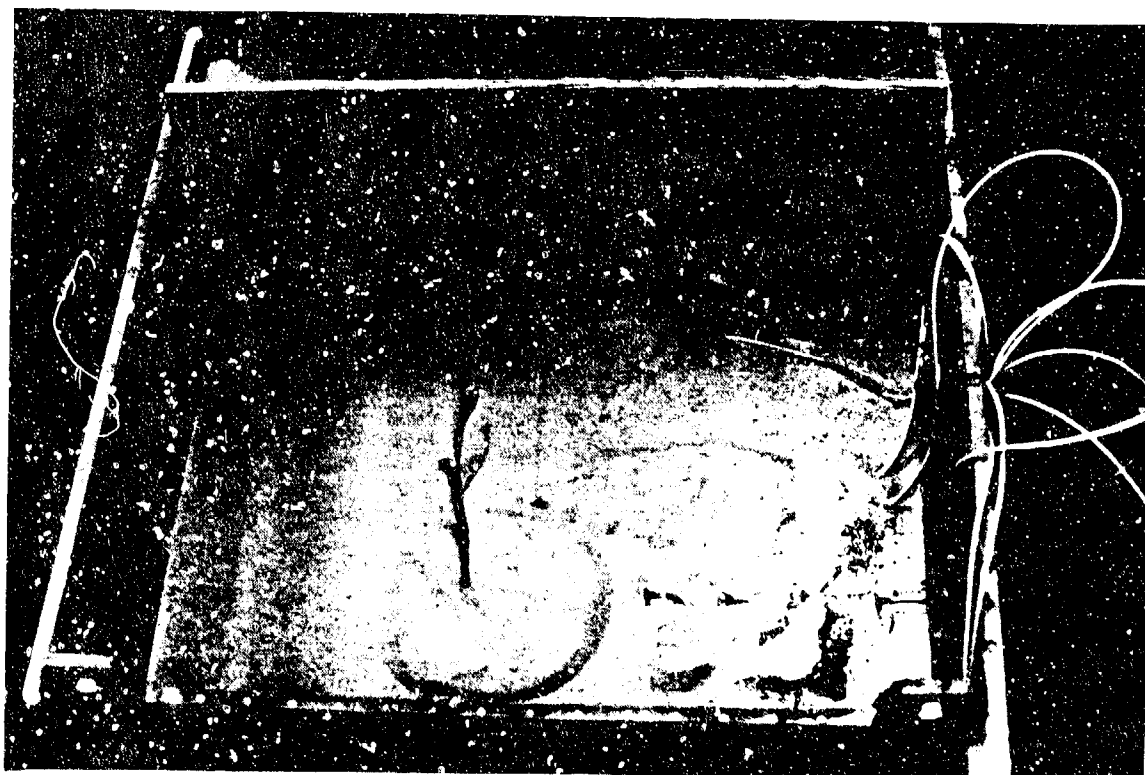
Figure 153. Buried Detonator

211
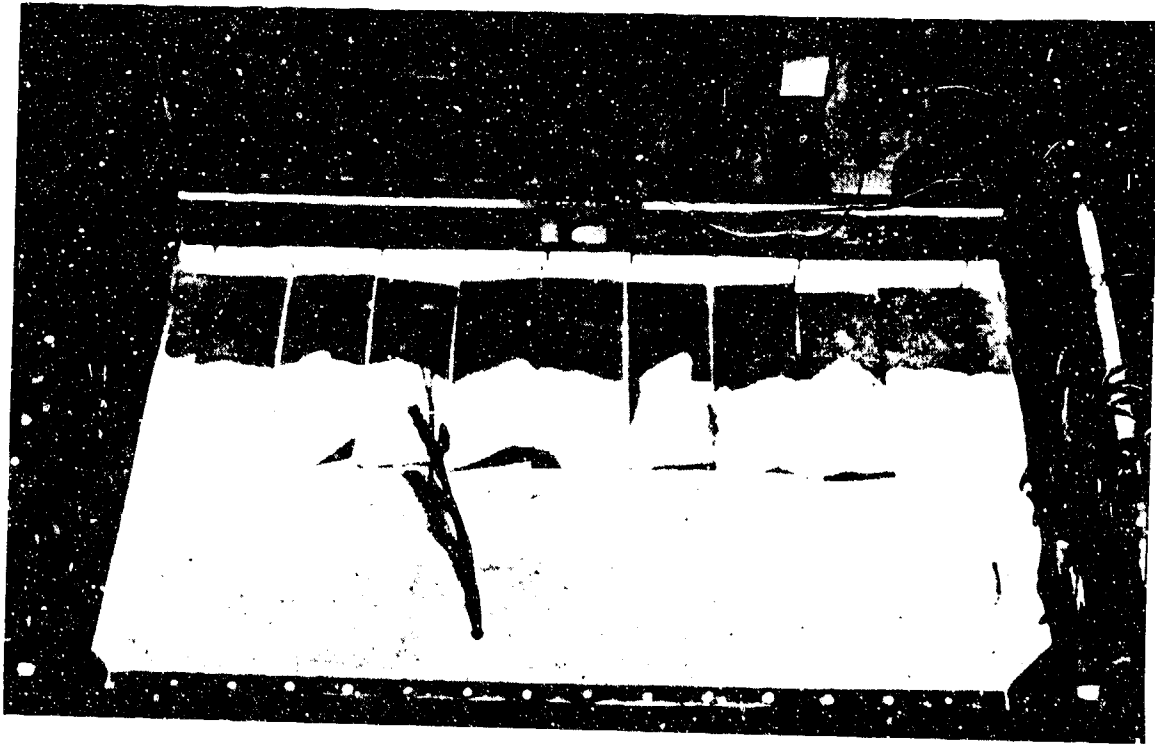
Figure 154. Fourth Level of Reinforcement

Figure 155.   Third Course of Facing Panels

Figure 156. Fifth Level of Reinforcement
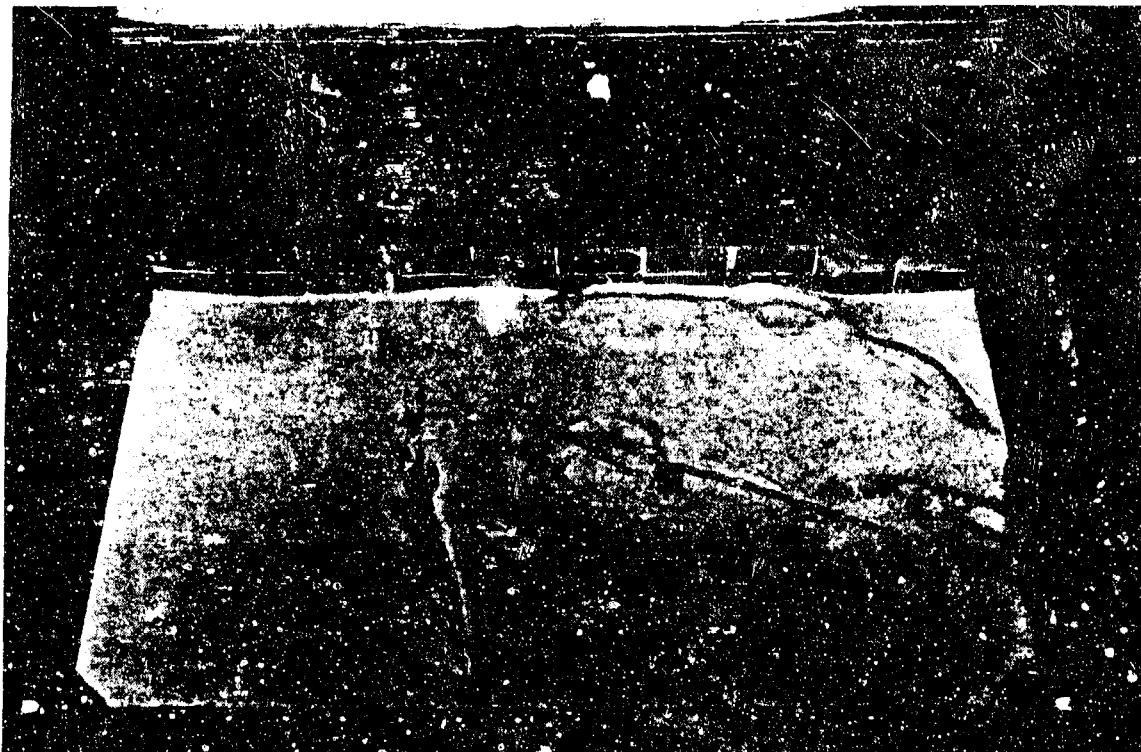
Figure 157.   Third Level of Instrumentation
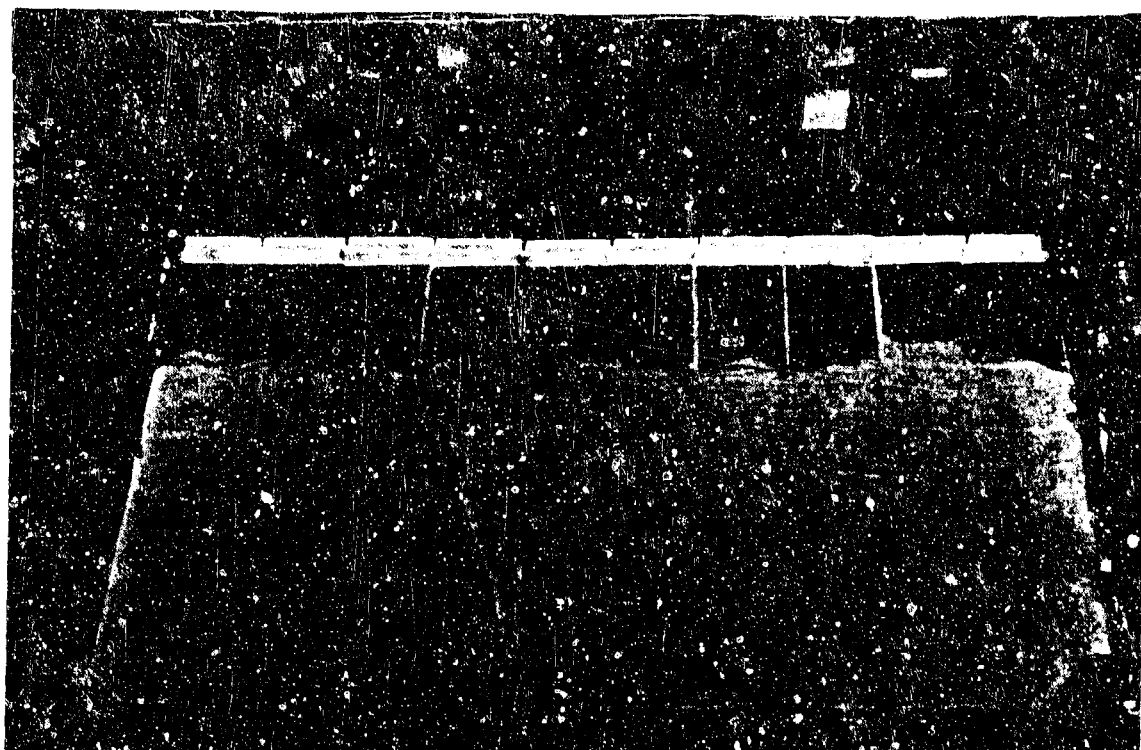
Figure 158. Sixth Level of Reinforcement
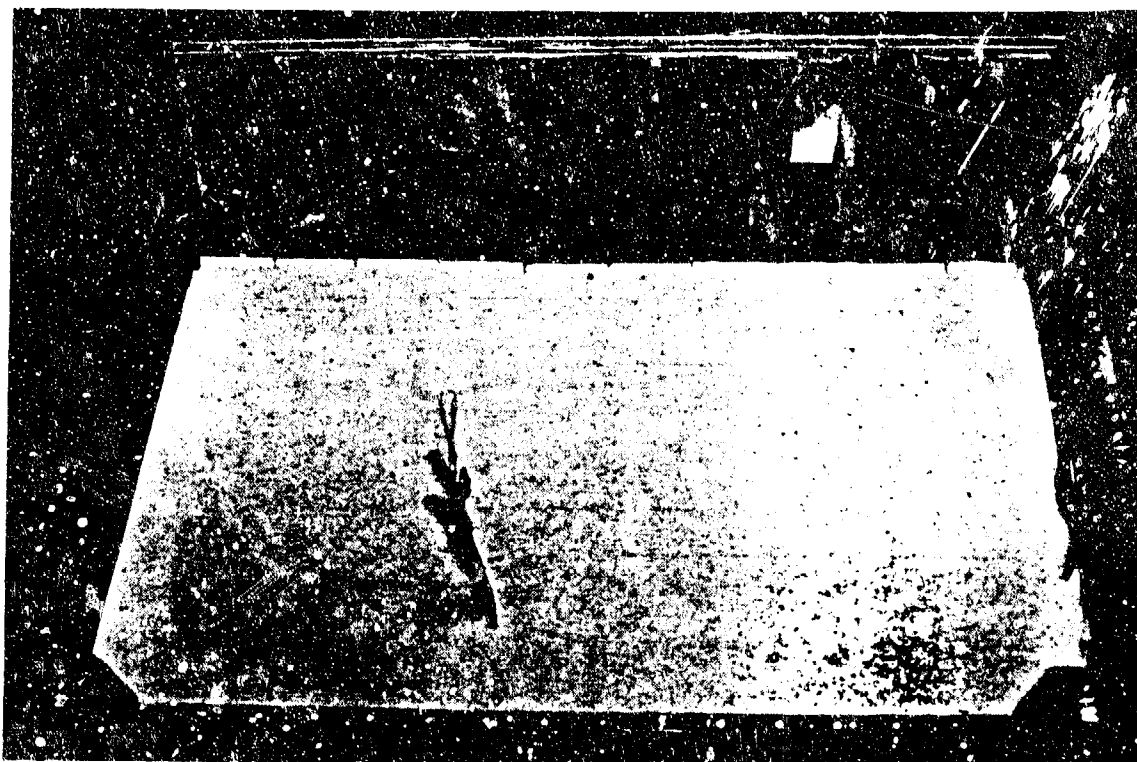
Figure 159. Completed Model

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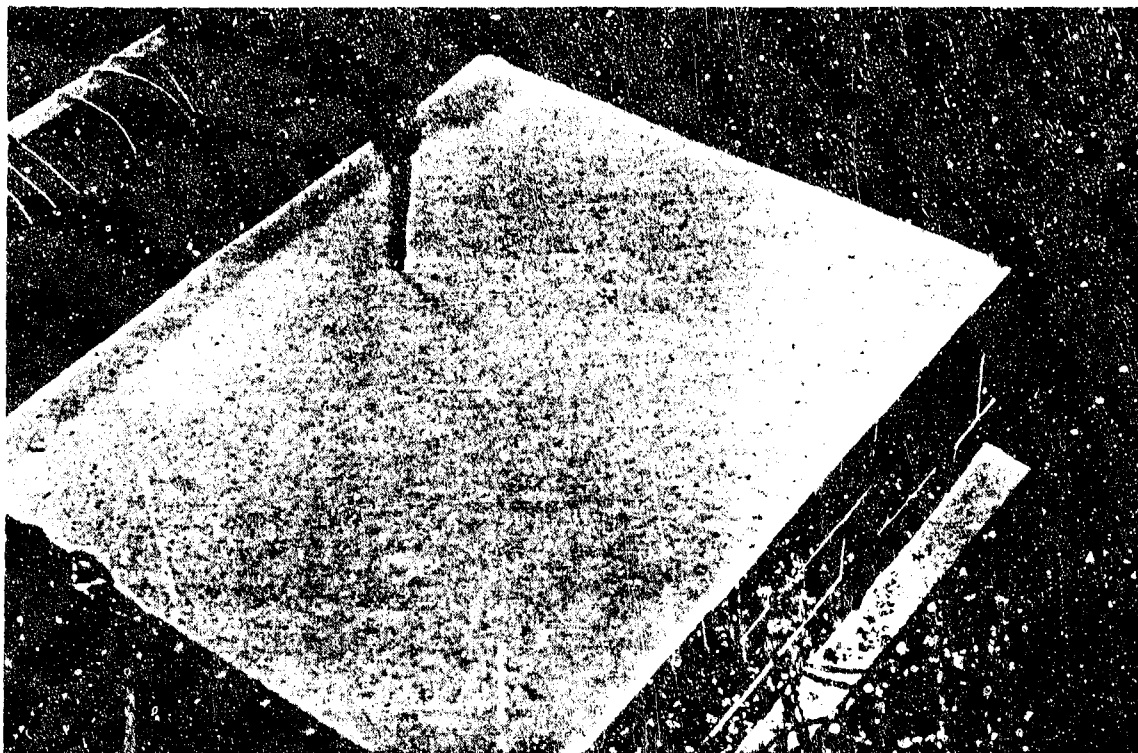
Figure 160. Model Mounted on Centrifuge
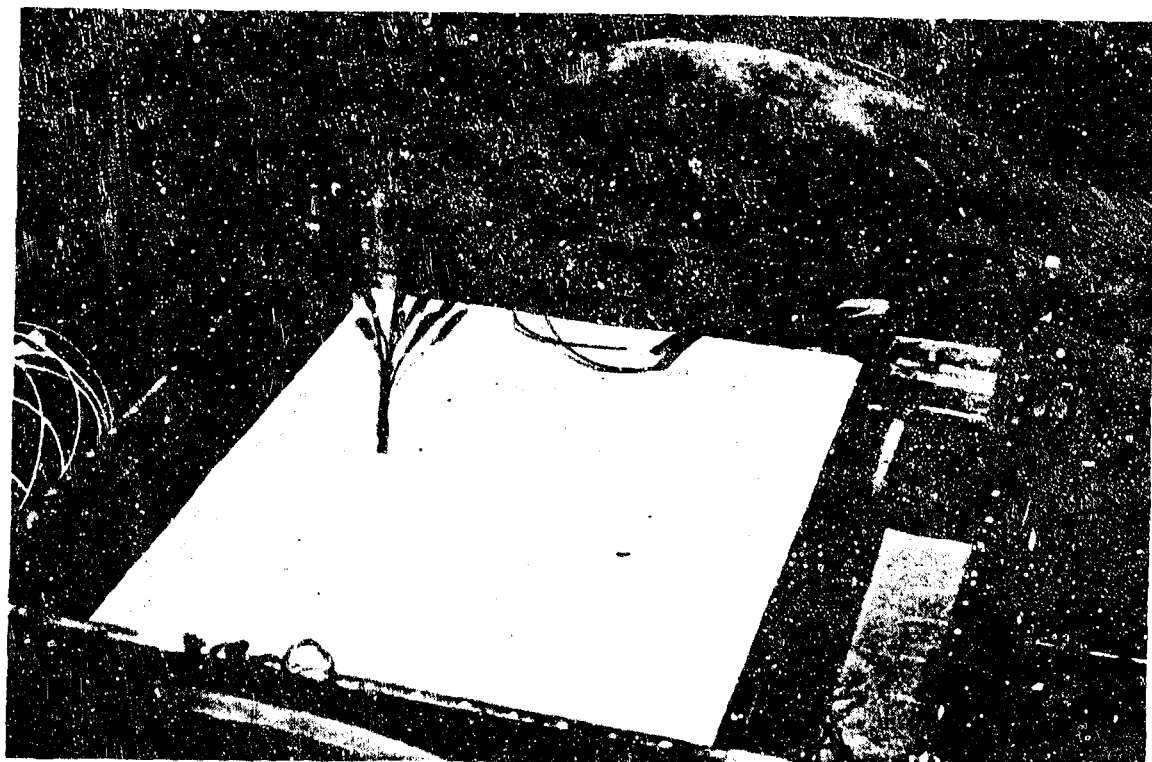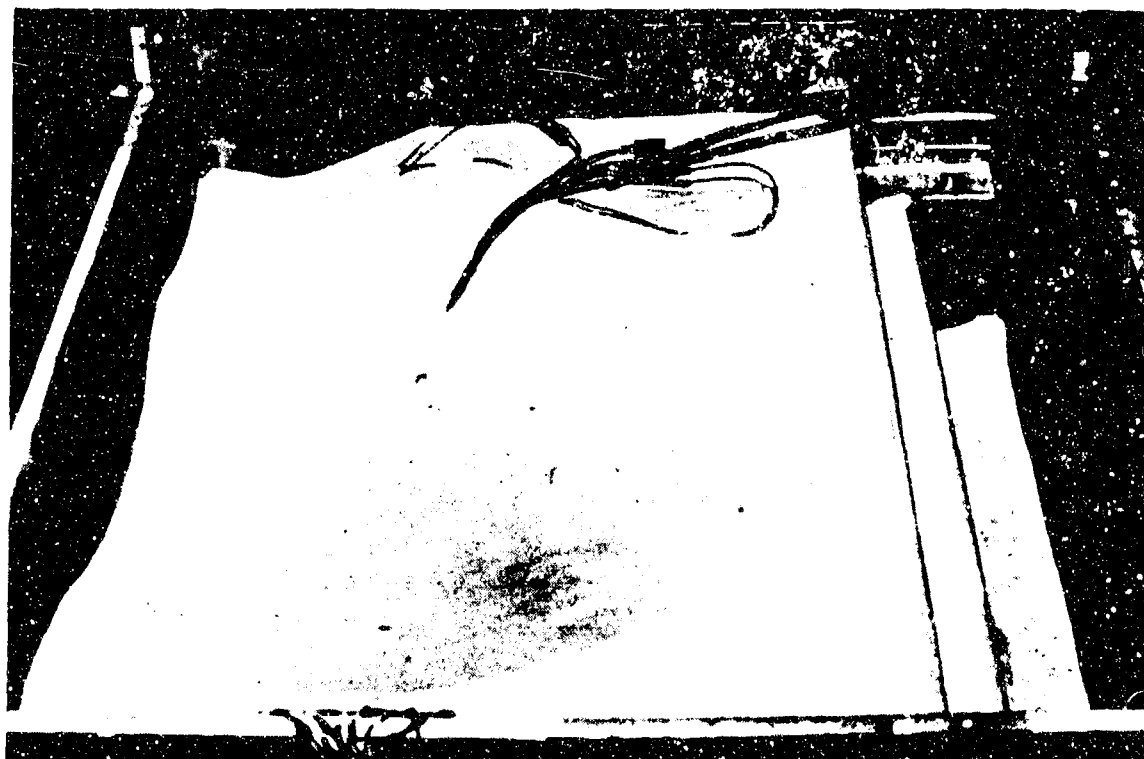
Figure 161.   Wired Detonator and Top Restraint

Figure 162.   Berm
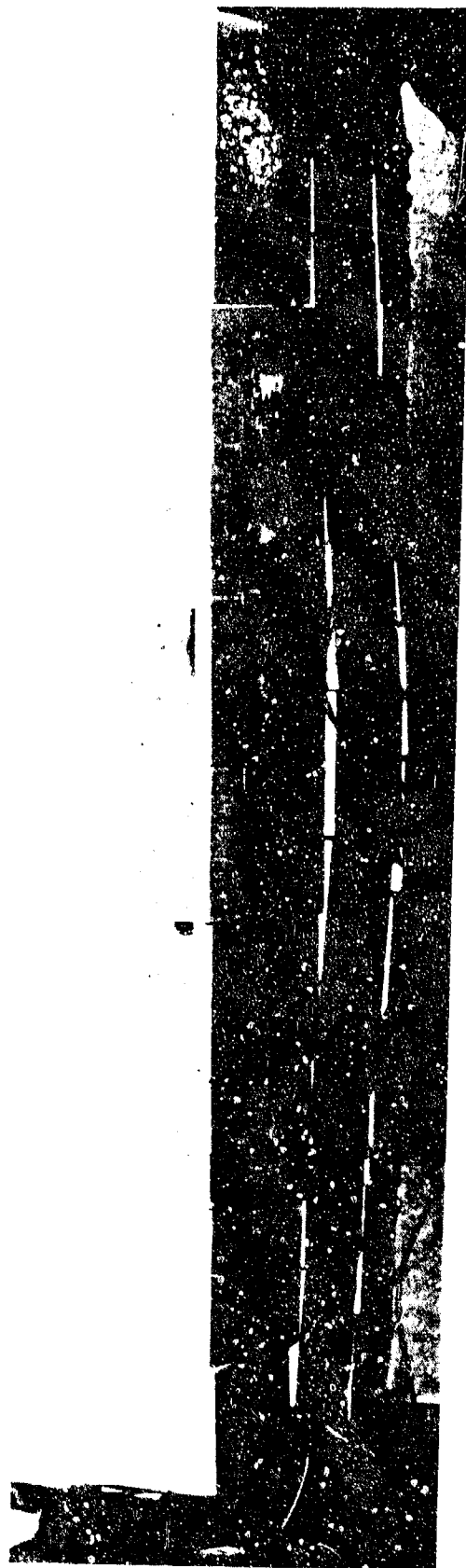
220
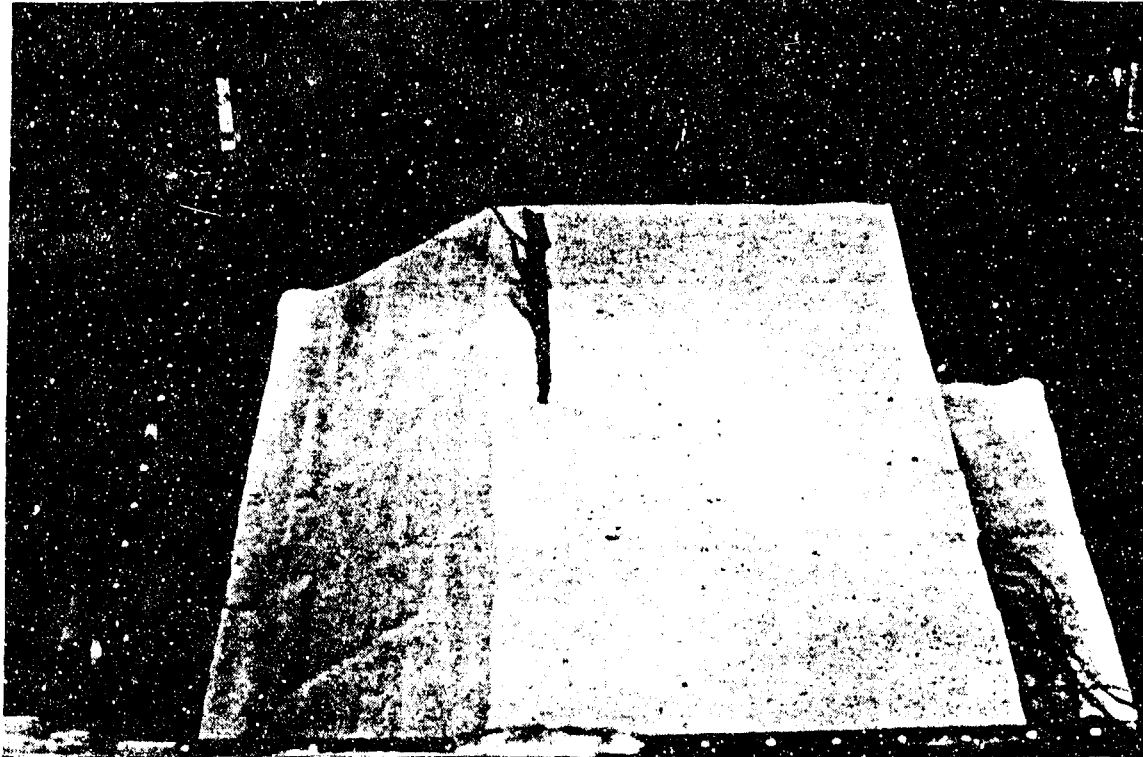
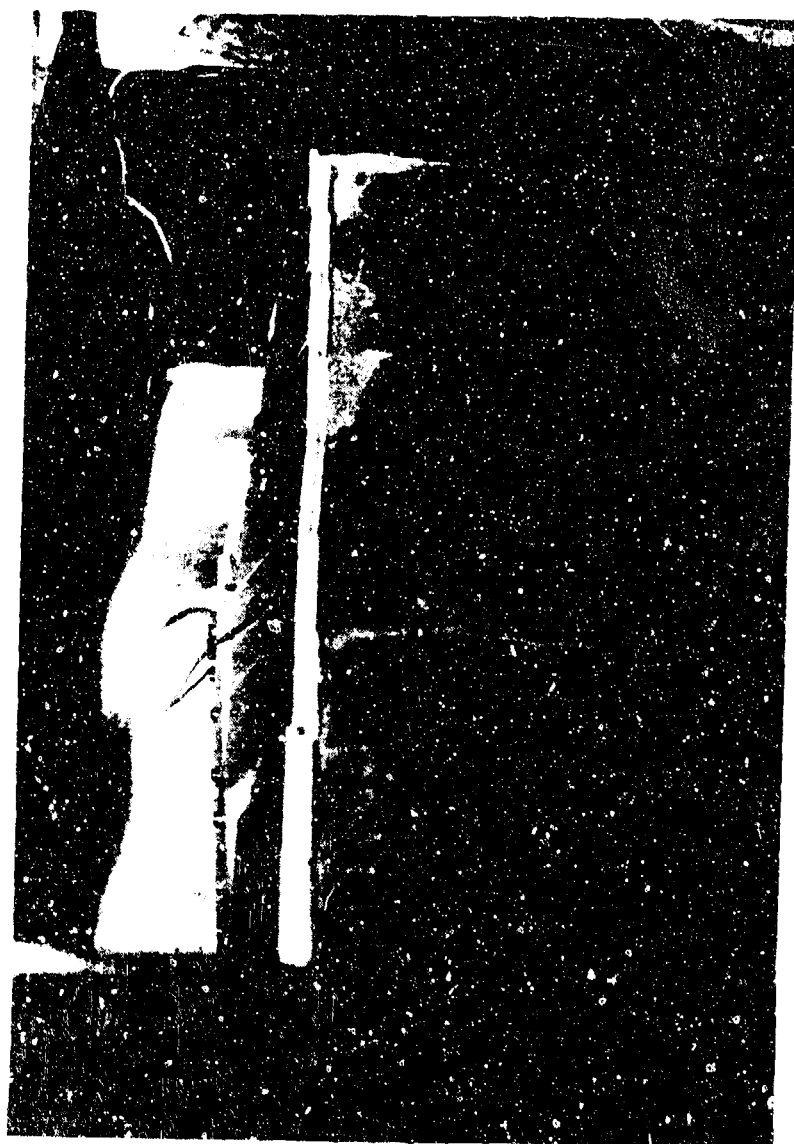Figure 163. Test 5- Crater

Figure 164. Test 5 Deformed Wall
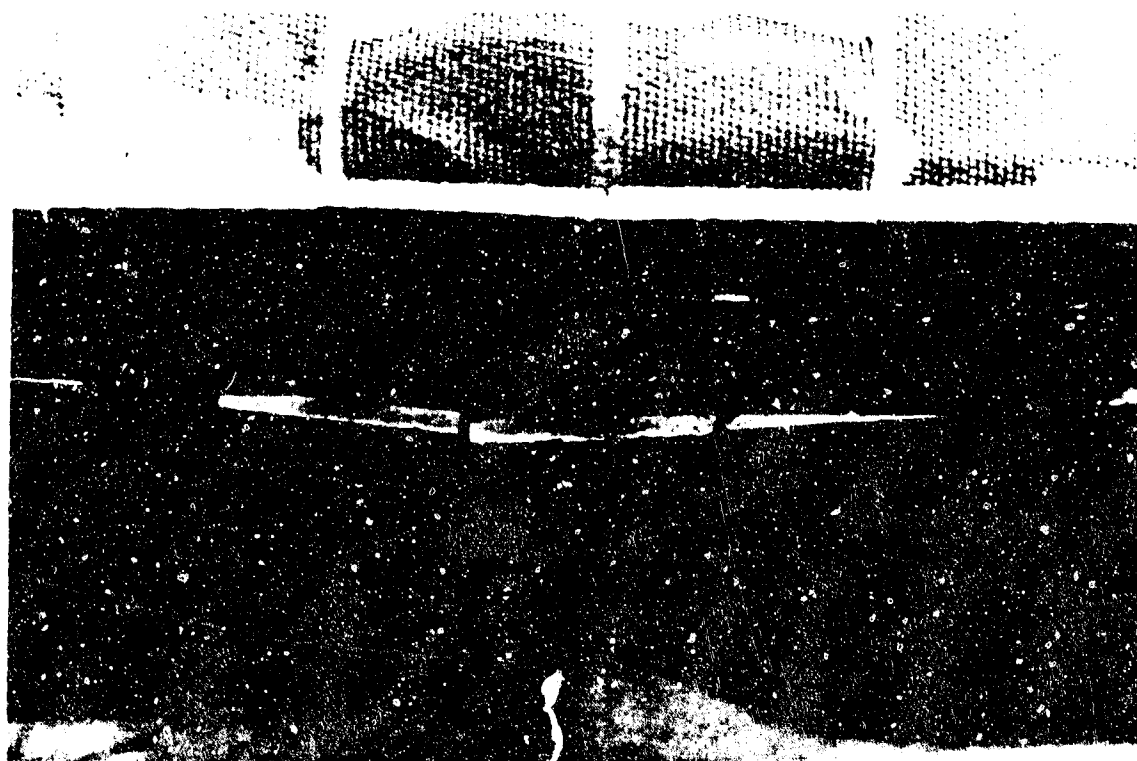
222

Figure 165. Test 1- Deformed Wall

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Figure 166. Test 1 Close-Up of Central Wall

Figure 167. Test 4- Deformed Wall

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Figure 168.   Test 4- Compression in Steel Reinforcing

Figure 169. Test 6 Deformed Wall

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